CORSO DI LAUREA
TECNICHE DI RADIOLOGIA MEDICA, PER IMMAGINI E RADIOTERAPIA

CORSO INTEGRATO
«FISICA E APPARECCHIATURE TC E RM – RMX012»

ANNO ACCADEMICO 2025/2026

Gemelli

UNIVERSITAS CATHOLICA SACRI CORDIS JESU MEDIOLANI

Insegnamento:
APPARECCHIATURE RISONANZA MAGNETICA
RMX054 - 13 ore MED/50 CFU 1

Formazione per l'eccellenza

ott. '25

2° anno I semestre

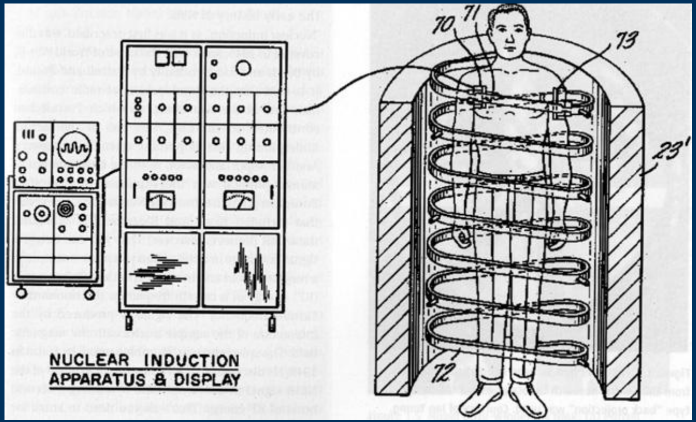
Fondazione Policlinico Universitario Agostino Gemelli IRCCS
Università Cattolica del Sacro Cuore

WORLD'S BEST HOSPITALS 2025 Newsweek statista

Insegnamento:
APPARECCHIATURE RISONANZA MAGNETICA
RMX054 - 13 ore MED/50 CFU 1

MRI – PASSATO, PRESENTE E FUTURO

ott. ’25



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Università Cattolica del Sacro Cuore

Insegnamento:
APPARECCHIATURE RISONANZA MAGNETICA
RMX054 - 13 ore MED/50 CFU 1

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https://www.variodyne.it

ott. '25

Fondazione Policlinico Universitario Agostino Gemelli IRCCS
Università Cattolica del Sacro Cuore

Formazione per l'eccellenza

Argomenti del Corso

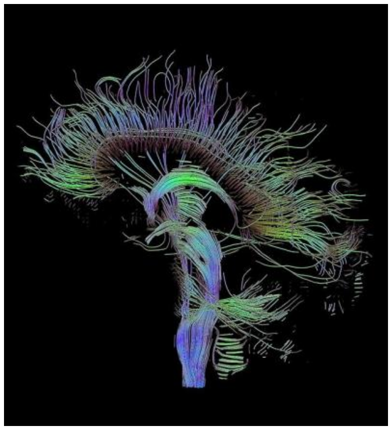
- Introduzione
- Sicurezza in RM
- Mdc e sicurezza
- **Passato, presente e futuro della RM**
- Fenomeno «RM» e principi fisici di base
- Magnete e i vari componenti
- Radiofrequenza e Bobine
- Gradienti
- Generazione di un'immagine RM
- Tecniche di acquisizione – *Parallel Imaging*
- Intelligenza artificiale – *Deep Learning*
- Artefatti
- Esame RM
- Sequenze RM
- Apparecchiature Fondazione

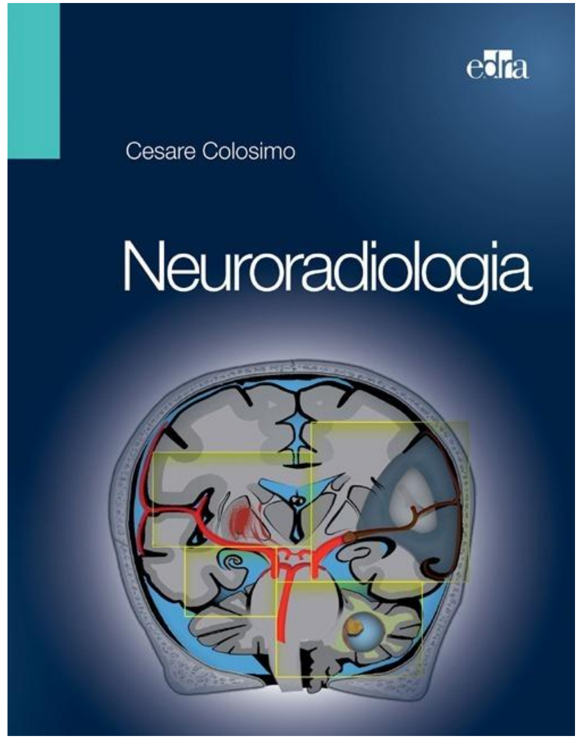
MRI

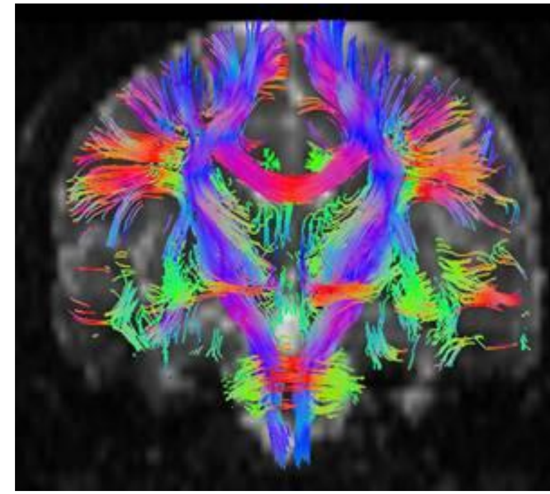

Istruzioni per l'uso
Risonanza Magnetica
MRI
Risonanza Magnetica
MRI

IRM – Imaging a Risonanza Magnetica

Formazione eccellenza







La **RM** è una metodica non invasiva che fornisce immagini di sezione multiplanari del corpo umano impiegando apparecchiature in grado di generare un potentissimo campo magnetico statico (B_0)…

… la RM sfrutta il fenomeno di risonanza per ottenere informazioni sui tessuti biologici …

MRI

Interazione tra onde radio e nuclei di H^+ delle diverse strutture del corpo in presenza di un forte campo magnetico

CENNI DI STORIA

La **Risonanza Magnetica Nucleare (RMN)** è un principio fisico che permette di misurare la precessione dello spin di alcuni nuclei atomici sottoposti ad un campo magnetico.
Scoperta indipendentemente nel 1946 dai fisici Felix Bloch ed Edward Purcell, per cui entrambi ricevettero il Premio Nobel per la fisica nel 1952, tra il 1950 e il 1970 venne utilizzata primariamente nell'analisi della chimica molecolare e della struttura dei materiali.

CENNI DI STORIA

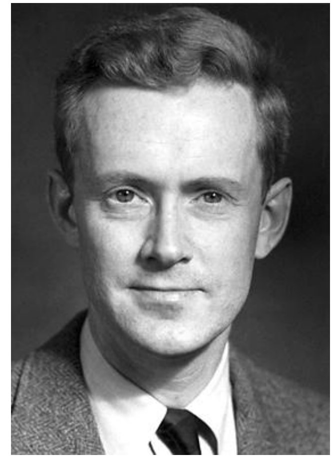
La **Risonanza Magnetica per Imaging (MRI)** è una tecnica utilizzata principalmente in campo medico per produrre immagini ad alta definizione dell'interno del corpo umano. L'MRI è basata sui principi della Risonanza Magnetica Nucleare (NMR), una tecnica spettroscopica usata dai ricercatori per ottenere informazioni di tipo microscopico, chimico e fisico, sulle molecole. La tecnica è stata chiamata "imaging mediante risonanza magnetica" piuttosto che "imaging mediante risonanza magnetica nucleare" a causa delle connotazioni negative associate negli ultimi anni '70 al termine "nucleare".

Quello che normalmente viene chiamato RMN in medicina è in realtà il Magnetic Resonance Imaging o MRI, ossia la visualizzazione di immagini tramite RM.

LA STORIA

Felix Bloch
Fisico
svizzero
23.10.1905-
10.9.1983

1946



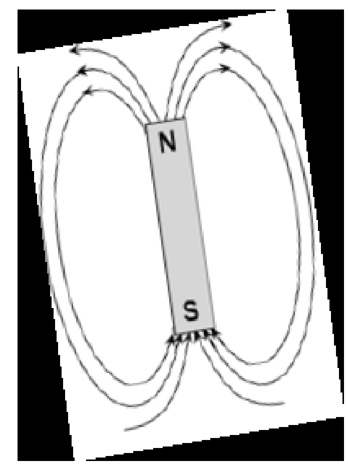
Edward Mills Purcell
Fisico
statunitense
30.8.1912 –
7.3.1997

Bloch e Purcell scoprirono il fenomeno della Risonanza Magnetica nel 1946 indipendentemente uno dall'altro

1952

Premio Nobel per la Fisica

Un nucleo si comporta come un magnete



Prize motivation: "for their development of new methods for nuclear magnetic precision measurements and discoveries in connection therewith"

I principi della meccanica quantistica

Paul Adrien Maurice Dirac (Bristol, 8 agosto 1902 – Tallahassee, 20 ottobre 1984) fisico e matematico britannico

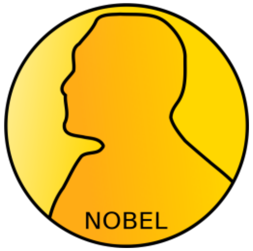
1930

Meccanica quantistica -- momento angolare di spin caratterizzato da un numero quantico di spin, che è una proprietà intrinseca del nucleo

Rabi ⟨réibi⟩ Isaac Isidor (Rynranov, Galizia, 1898 - New York 1988)

1937

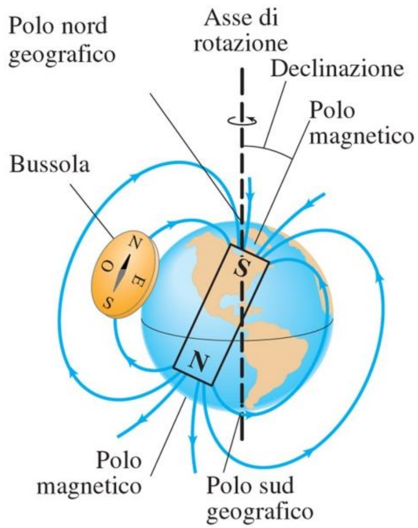
Storicamente il *primo esperimento di RMN* è stato quello dell'americano Rabi (v., 1937), effettuato su fasci atomici per la misura dei momenti magnetici di vari nuclei atomici.

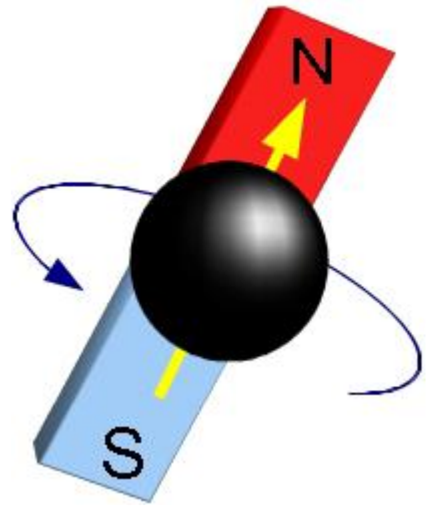


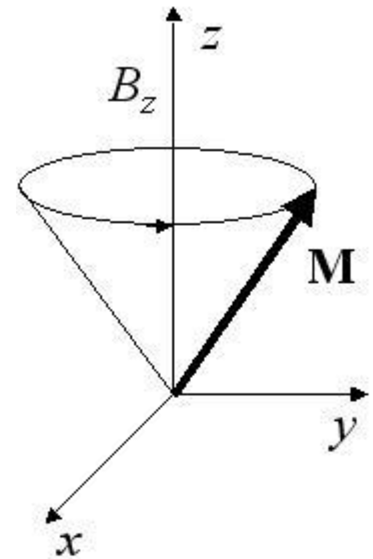
1944 Nobel per la fisica … "per il suo metodo della risonanza per la registrazione delle proprietà magnetiche dei nuclei atomici"

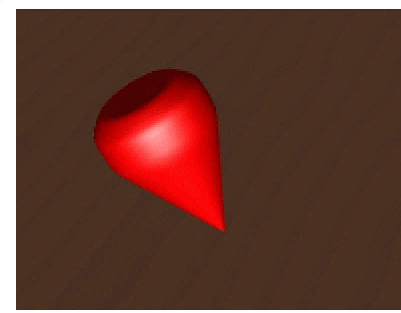
Equazioni di Bloch

Felix Bloch









Una particella carica, come un protone, che ruoti intorno al proprio asse genera un campo magnetico ("momento magnetico")

$$\frac{dM_{x'}}{dt} = (\omega_o - \omega)M_{y'} - \frac{M_{x'}}{T_2}$$

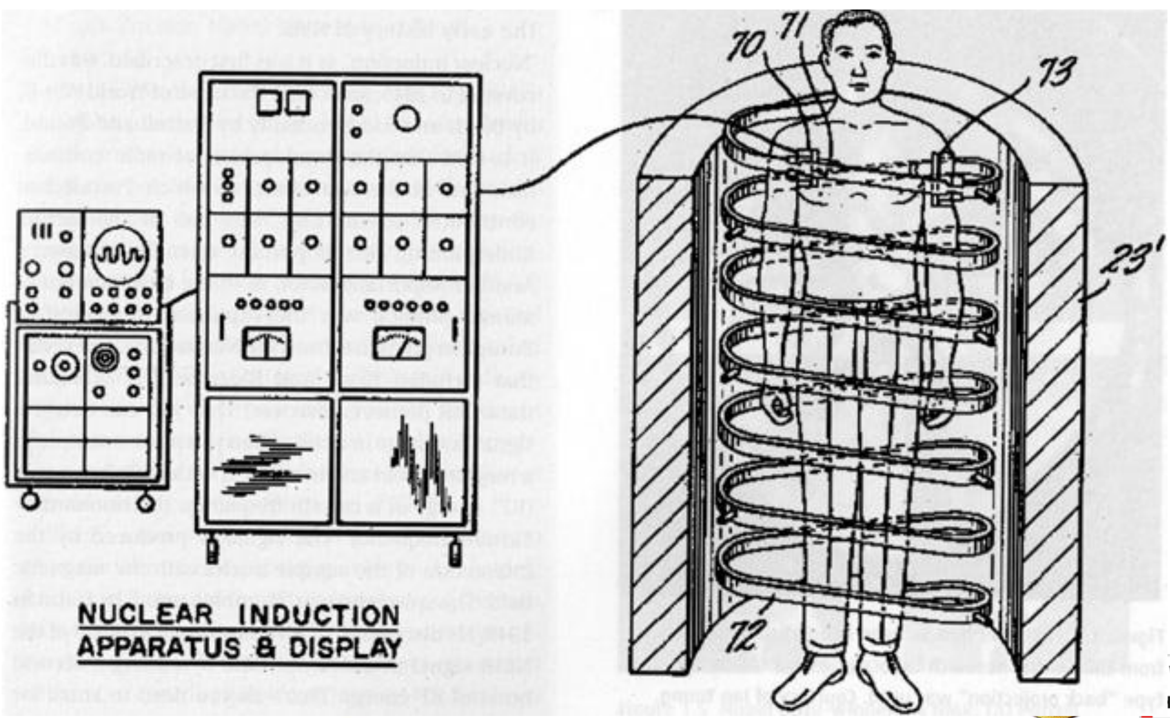
$$\frac{dM_{y'}}{dt} = -(\omega_o - \omega)M_{x'} + 2\pi\gamma B_1 M_z - \frac{M_{y'}}{T_2}$$

$$\frac{dM_z}{dt} = -2\pi\gamma B_1 M_{y'} - \frac{(M_z - M_{z_o})}{T_1}$$

Raymond Vahan Damadian
USA 16 marzo 1936

1971

Fu Raymond Damadian nel 1971 a dimostrare, con esperimenti su cavie da laboratorio, che i tempi di rilassamento magnetico-nucleari dei tessuti sani erano differenti da quelli dei tessuti tumorali



LA STORIA

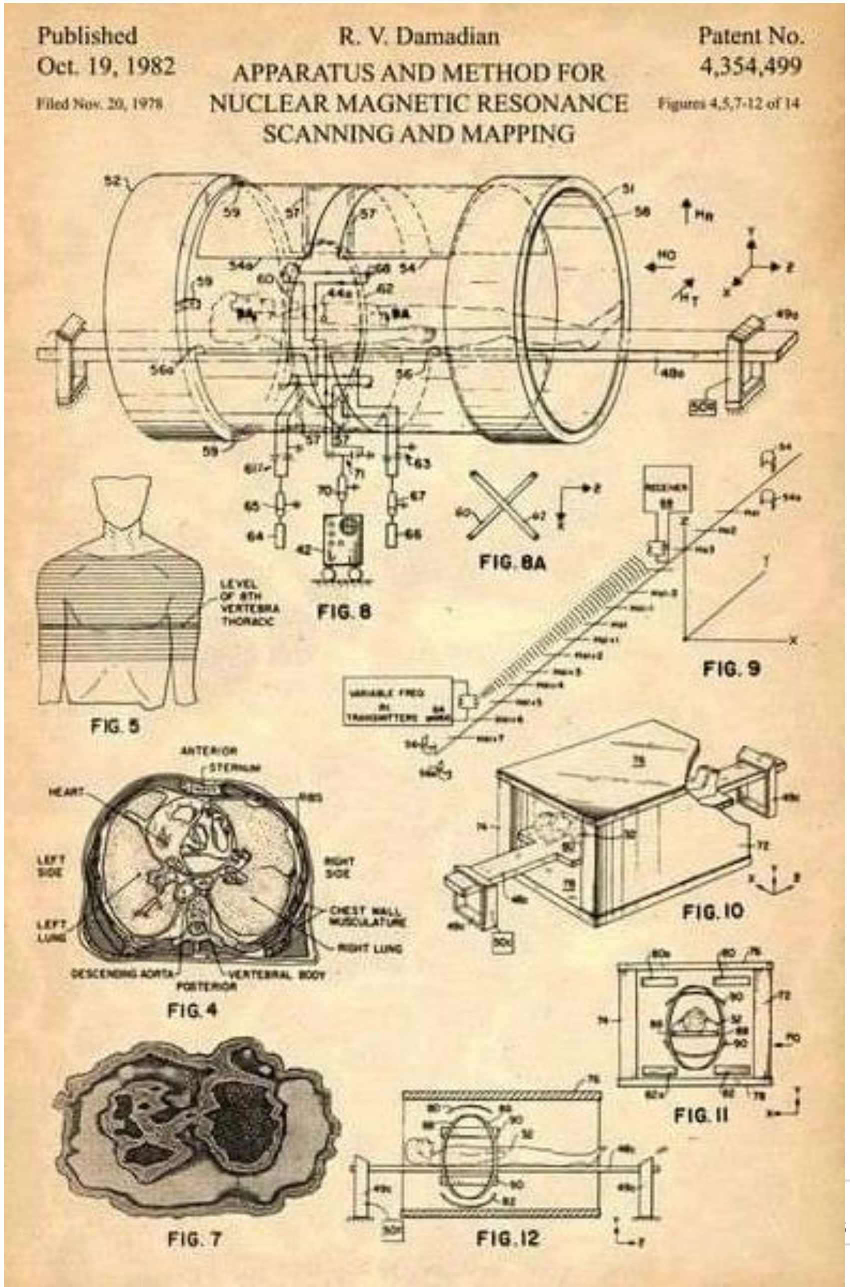

Published
Oct. 19, 1982
Filed Nov. 20, 1978
R. V. Damadian
APPARATUS AND METHOD FOR
NUCLEAR MAGNETIC RESONANCE
SCANNING AND MAPPING
Patent No.
4,354,499
Figures 4,5,7-12 of 14
FIG. 8A
FIG. 8
FIG. 9
FIG. 5
LEVEL OF 8TH VERTEBRA THORACIC
ANTERIOR
STERNUM
HEART
LEFT SIDE
RIGHT SIDE
LEFT LUNG
CHEST WALL MUSCULATURE
RIGHT LUNG
DESCENDING AORTA
VERTEBRAL BODY
POSTERIOR
FIG. 4
FIG. 10
FIG. 11
FIG. 7
FIG. 12

Image Formation by Induced Local Interactions: Examples Employing Nuclear Magnetic Resonance

1973

nature.com

16 March 1973 Image Formation by Induced Local Interactions: Examples Employing Nuclear Magnetic Resonance

P. C. LAUTERBUR

Nature 242, 190-191

doi:10.1038/242190a0

Formazione per l'eccellenza

Peter Mansfield

Londra 1933 -

1973

Il contributo di Mansfield consiste nell'aver mostrato come i segnali radio provenienti dalla MR possono essere matematicamente analizzati, trasformandoli in una immagine utile a fini diagnostici.

Inoltre Mansfield ha scoperto la tecnica di echo-planar imaging, in grado di rendere possibile l'ottenimento veloce di immagini dalla MR fino al punto da visualizzare immagini in movimento degli organi umani, come per esempio del cuore, e lo sviluppo della risonanza magnetica funzionale.

CENNI DI STORIA

Formazione per l'eccellenza

Paul Lauterbur (born 1929), Urbana, Illinois, USA, discovered the possibility to create a two-dimensional picture by introducing gradients in the magnetic field. By analysis of the characteristics of the emitted radio waves, he could determine their origin. This made it possible to build up two-dimensional pictures of structures that could not be visualized with other methods.

ıasive
ıt and
edicine
ɡnetic
ies have
ıaging,
ics and

ency that is dependent on the strength of the magnetic field. Their energy can be increased if they absorb radio waves with the same frequency (resonance). When the atomic nuclei return to their previous energy level, radio waves are emitted. These discoveries were awarded the Nobel Prize in Physics in 1952. During the following decades, magnetic resonance was used mainly for studies of the chemical structure of substances. In the beginning of the 1970s, this year's Nobel Laureates made pioneering contributions, which later led to the applications of magnetic resonance in medical imaging.

Press Release

6 October 2003

The Nobel Assembly at Karolinska Institutet has today decided to award

The Nobel Prize

Paul C Lauterb

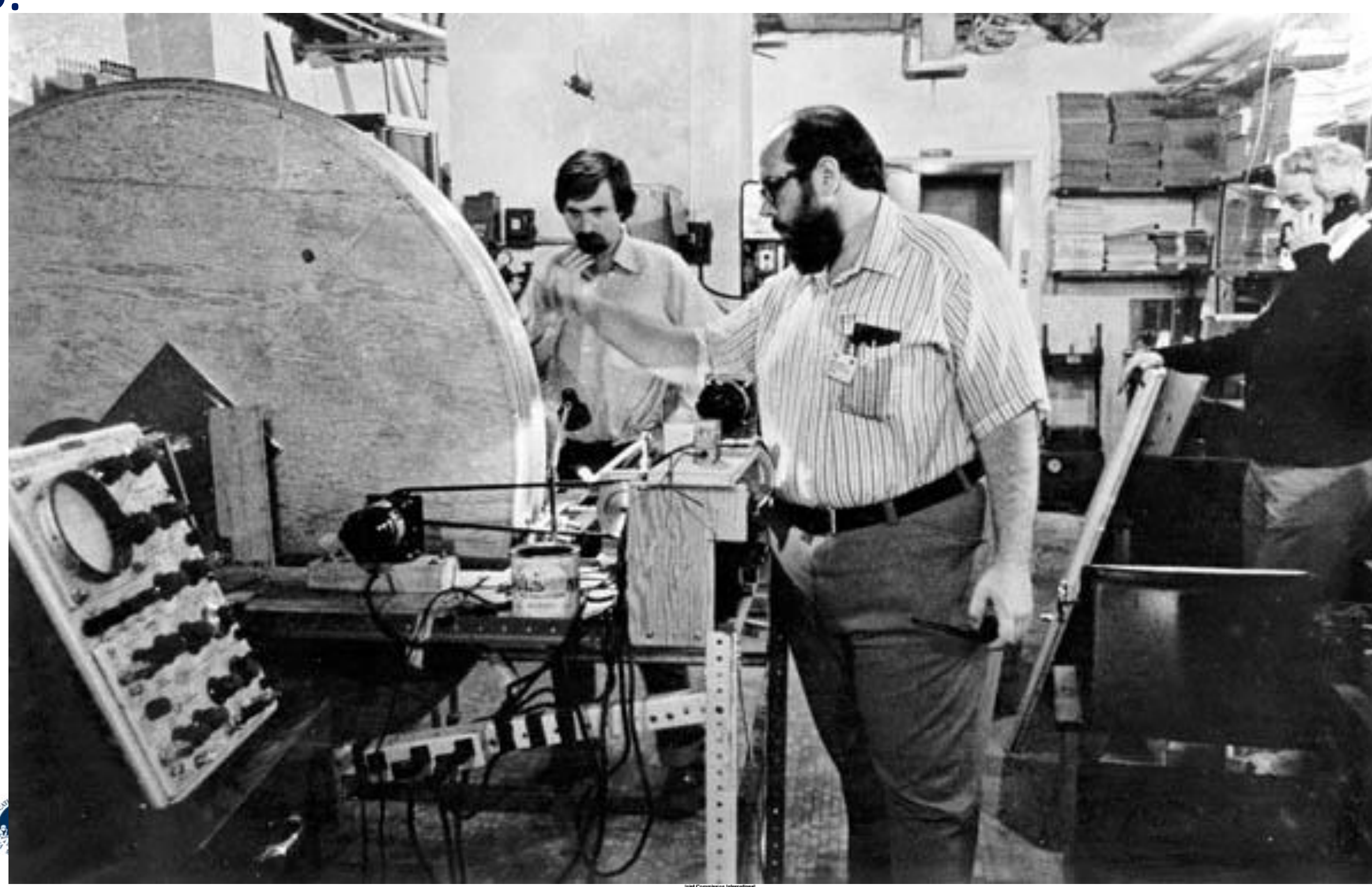
for their discov

Peter Mansfield (born 1933), Nottingham, England, further developed the utilization of gradients in the magnetic field. He showed how the signals could be mathematically analysed, which made it possible to develop a useful imaging technique. Mansfield also showed how extremely fast imaging could be achievable. This became technically possible within medicine a decade later.

/laureates/2003/press.html

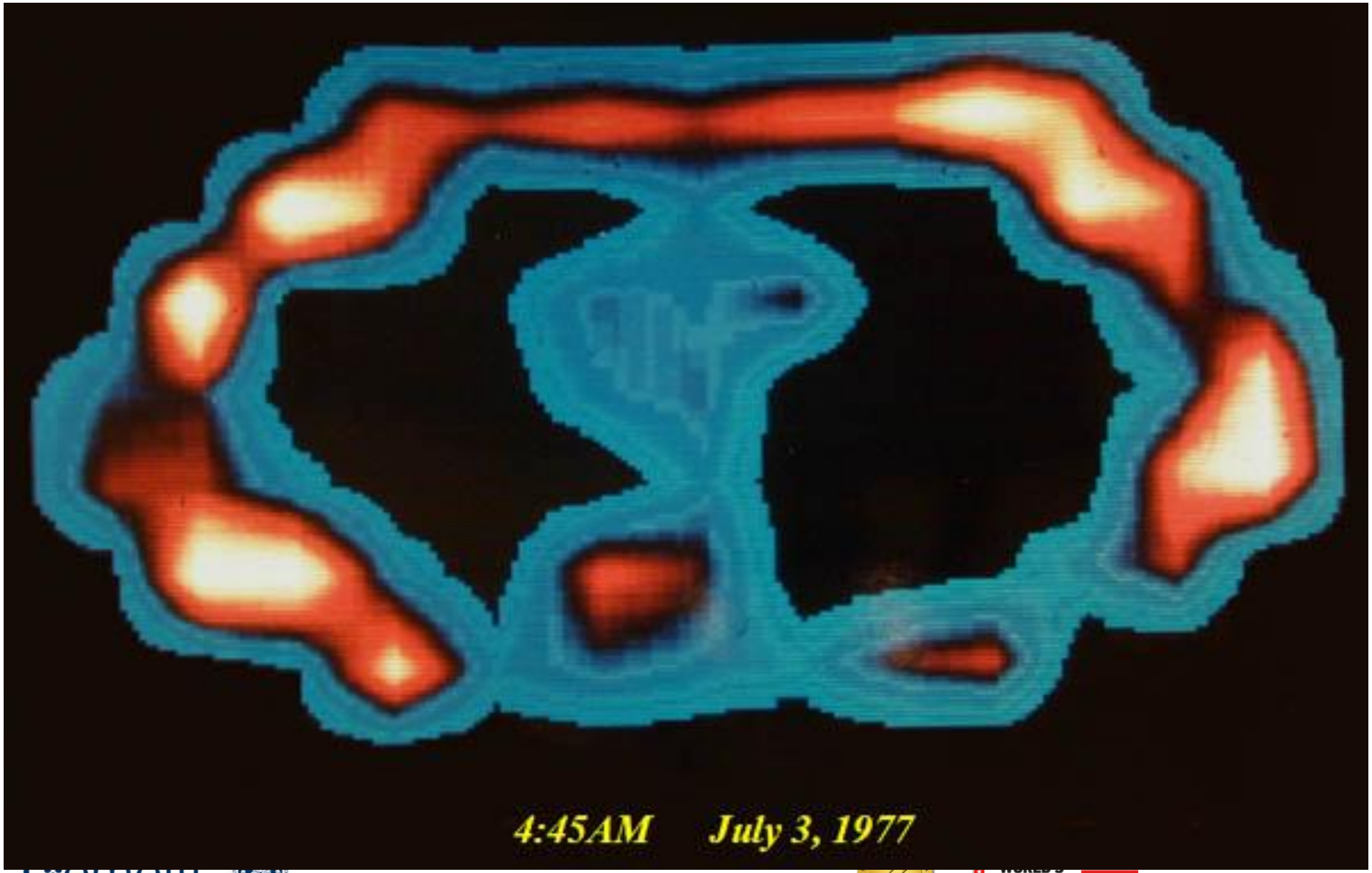
La prima MRI

Damadian went on to build the first MRI scanner by hand, assisted by his two post-doctoral students, Michael Goldsmith and Larry Minkoff at New York’s Downstate Medical Center and achieved the first MRI scan of a ***healthy human body in 1977*** and a ***human body with cancer in 1978***.



La prima MRI

Figura. The interpolated image of the Minkoff scan and the first ever MRI scan of a live human being (4:45 AM July 3, 1977).



La prima MRI

Figura. L. Minkoff in Indomitable with some "room to spare" inside the Goldsmith receiver coil.

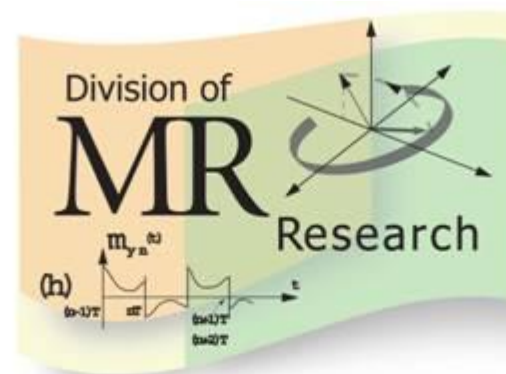
Gemelli

STORIA

Nel **1975 Richard Ernst** propose un processo di codifica di fase e di codifica in frequenza delle radiofrequenze e l'introduzione della trasformata di Fourier nell'analisi dei dati ottenuti.

Richard Robert Ernst (Winterthur, 14 agosto 1933) è un chimico svizzero

Nel 1980, Edelstein ed i suoi collaboratori sperimentarono l'imaging del corpo usando la tecnica di Ernst, grazie alla quale una singola immagine poteva essere acquisita in circa cinque minuti. Il tempo di imaging verrà drasticamente ridotto a circa cinque secondi, senza significativi cambiamenti della qualità dell'immagine, a partire dal 1986.



William A. Edelstein,
New York 1962 -

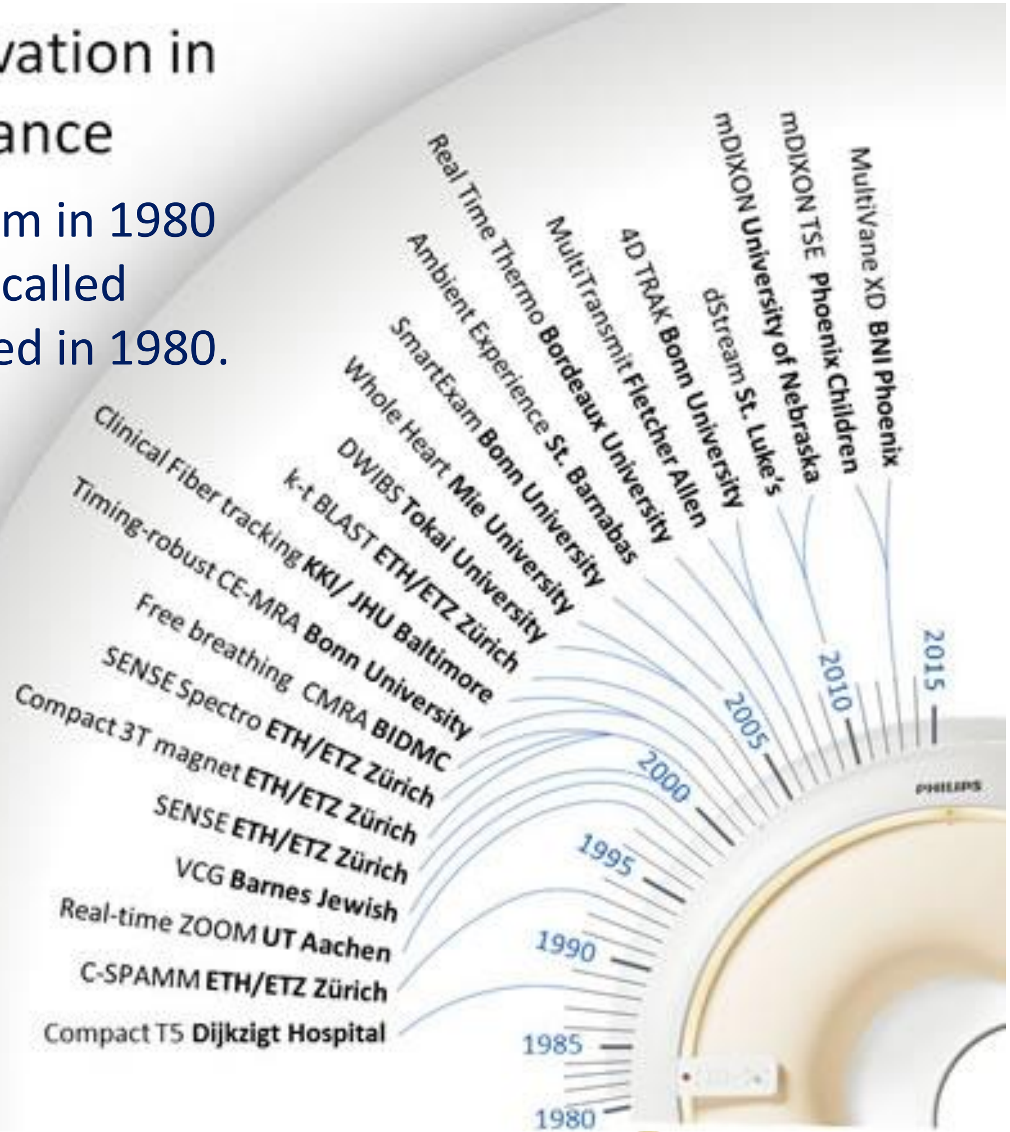
La prima MRI

FONAR The Inventor of MR Scanning™

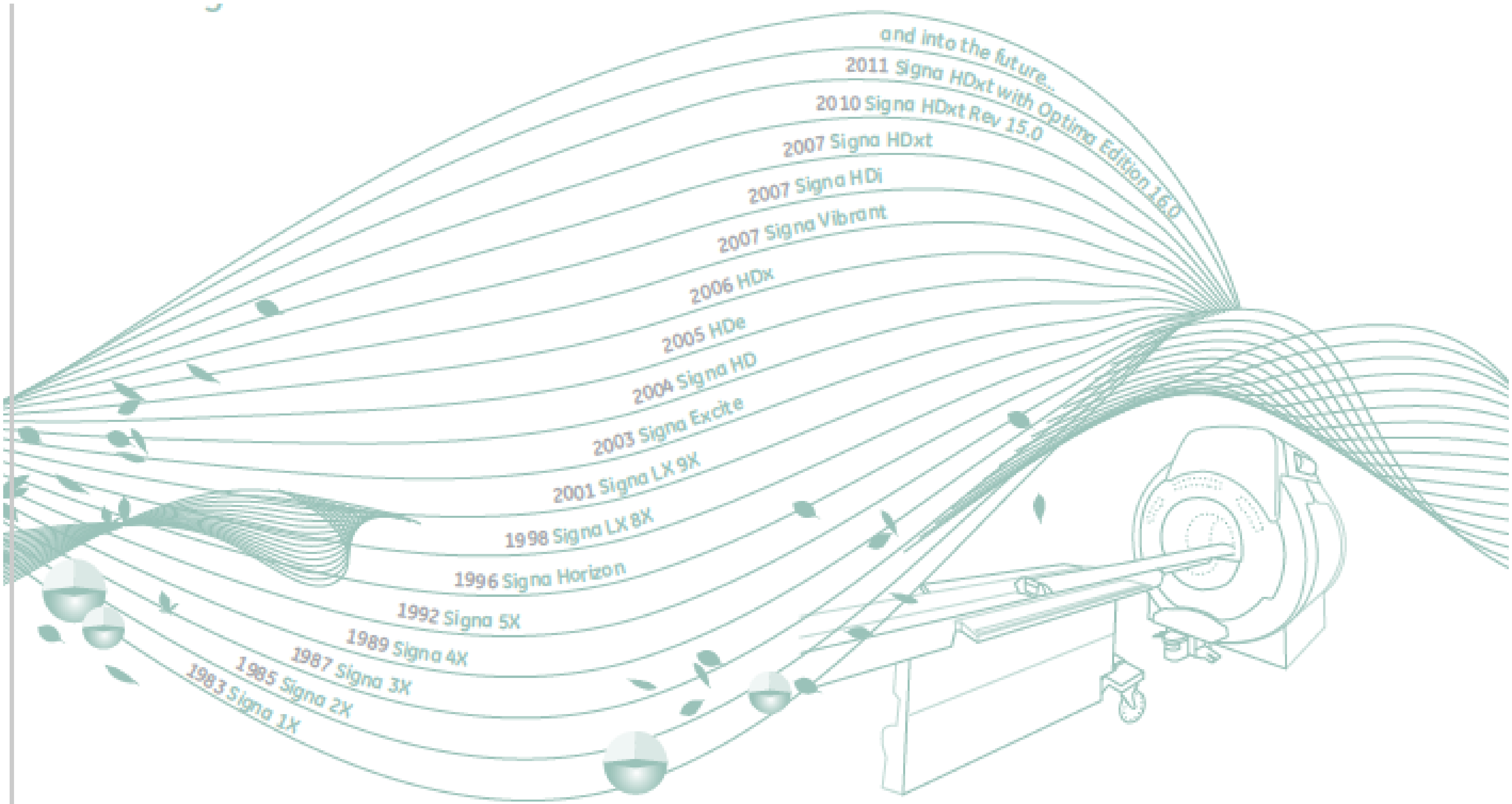
Figura. Raymond Damadian, Larry Minkoff and Michael Goldsmith with "Indomitable" and its iced liquid helium and liquid nitrogen ports: the world's first supercooled, superconducting MR scanner and the world's first MRI machine.

La prima MRI - Philips

First Philips MRI system in 1980
Our first MRI system, called **Proton**, was introduced in 1980.



GE


and into the future...
2011 Signa HDxt with Optima Edition 16.0
2010 Signa HDxt Rev 15.0
2007 Signa HDxt
2007 Signa HDi
2007 Signa Vibrant
2006 HDx
2005 HDe
2004 Signa HD
2003 Signa Excite
2001 Signa LX 9X
1998 Signa LX 8X
1996 Signa Horizon
1992 Signa 5X
1989 Signa 4X
1987 Signa 3X
1985 Signa 2X
1983 Signa 1X

RM e ISPESL (ora INAIL)

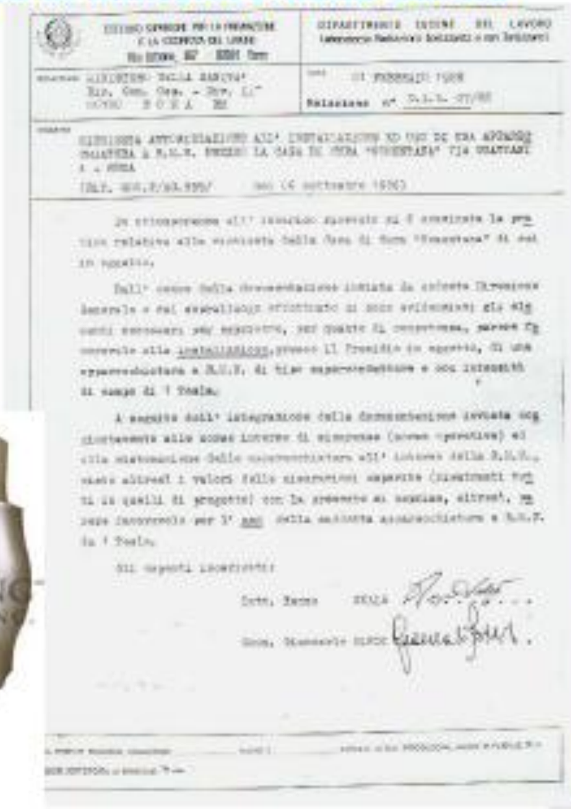
1985 : arriva la Risonanza Magnetica

INAIL
ISTITUTO NAZIONALE PER L'ASSICURAZIONE CONTRO GLI INFORTUNI SUL LAVORO

Dipartimento Igiene del Lavoro - ex ISPESL


Roma 6 SET 1986
Ministero della Sanità
IL DIRETTORE GENERALE
1951266

L'ISPESL si esprime sulle richieste di autorizzazione all'installazione presentate al Ministero della Sanità


DIPARTIMENTO IGIENE DEL LAVORO

RM PHILIPS

Formazione per l'eccellenza

Classic magnet technology
~1,500 liters of liquid helium

BlueSeal micro-cooling technology
~7 liters of liquid helium

PHILIPS

BlueSeal magnet

RM PHILIPS

BlueSeal magnet design	
Field strength	1.5T
Magnet design	Ultra compact, lightweight and sealed
Magnet weight (with cryogen)	2,300 kg (5,071 lbs)
Minimum siting limitation	3,700 kg (8,157 lbs)
Open bore diameter	70 cm (incl. shim, gradient & QBC)
Maximum FOV	55 cm × 55 cm × 50 cm

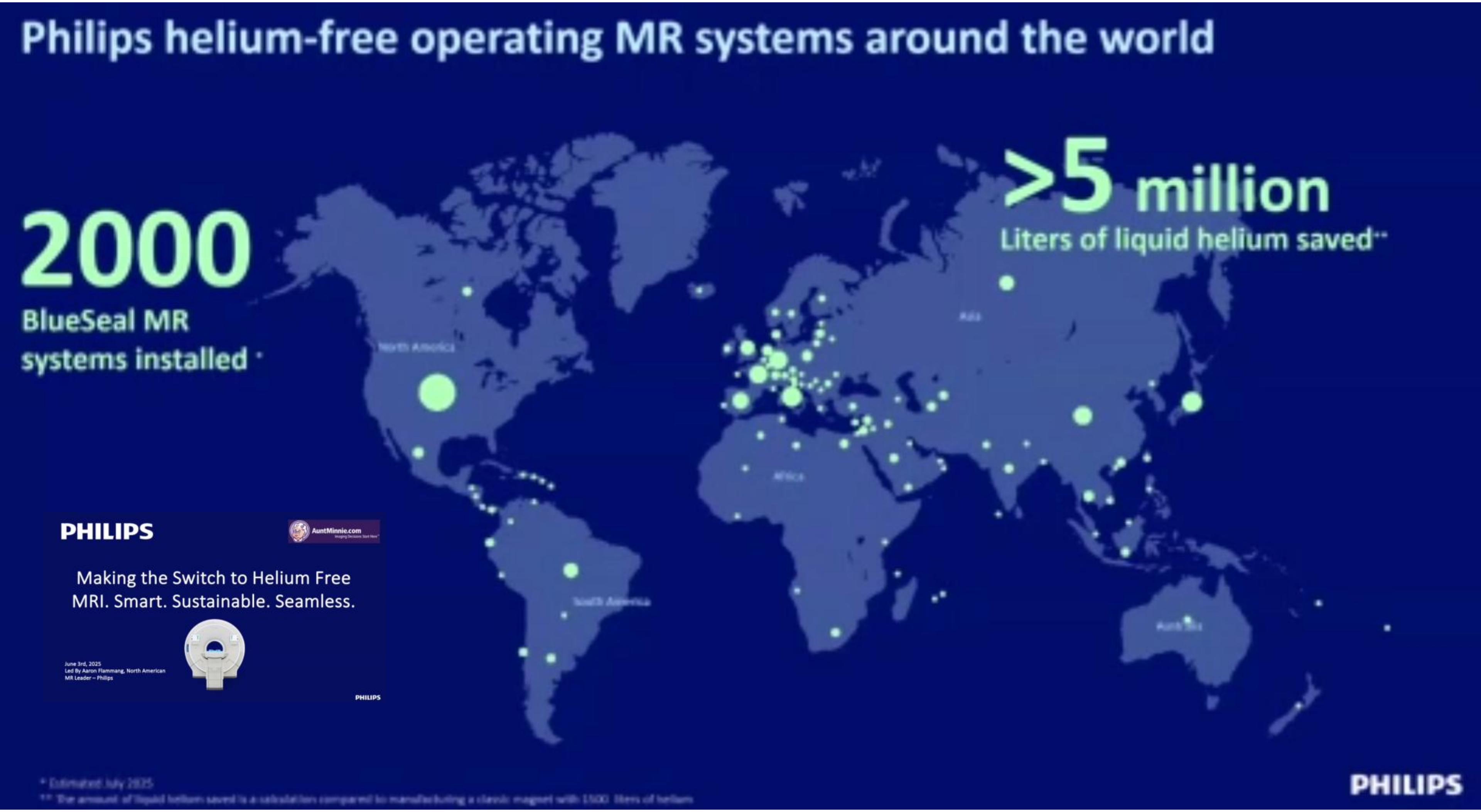
BlueSeal micro-cooling system	
Type of cryogen	Liquid helium (~7 liters)
Micro-cooling technology	Yes
Cryogen boil-off rate	Not applicable, fully sealed
Cryogen refill interval	Not applicable, fully sealed
Vent-pipe requirements	Not applicable, fully sealed

BlueSeal adaptive-intelligence	
Type of magnet controller	Digital, adaptive-intelligent
Self ramp-up unit	Yes, digital
Self ramp-down unit	Yes, digital
BlueSeal EasySwitch	Yes, adaptive-intelligent
EasySwitch innovations	Yes, magnet UPS, air-cooled compressor and 24/7 monitored e-Alert

PHILIPS

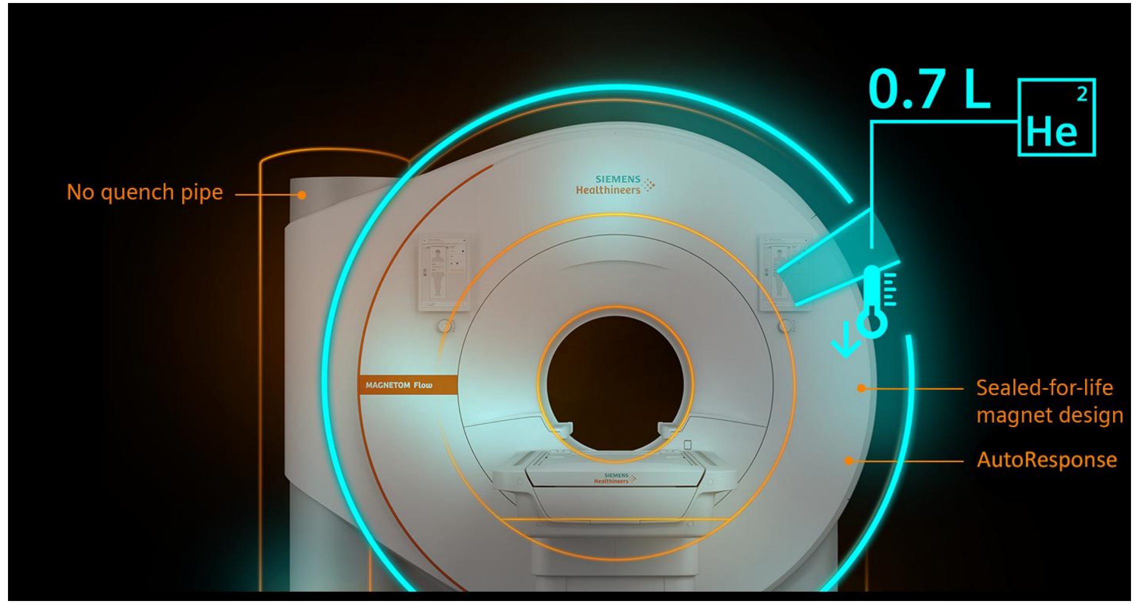
BlueSeal magnet

RM PHILIPS



Philips helium-free operating MR systems around the world
2000
BlueSeal MR systems installed *
>5 million
Liters of liquid helium saved**
PHILIPS
AuntMinnie.com
Making the Switch to Helium Free MRI. Smart. Sustainable. Seamless.
PHILIPS

RM SIEMENS MAGNETOM FLOW

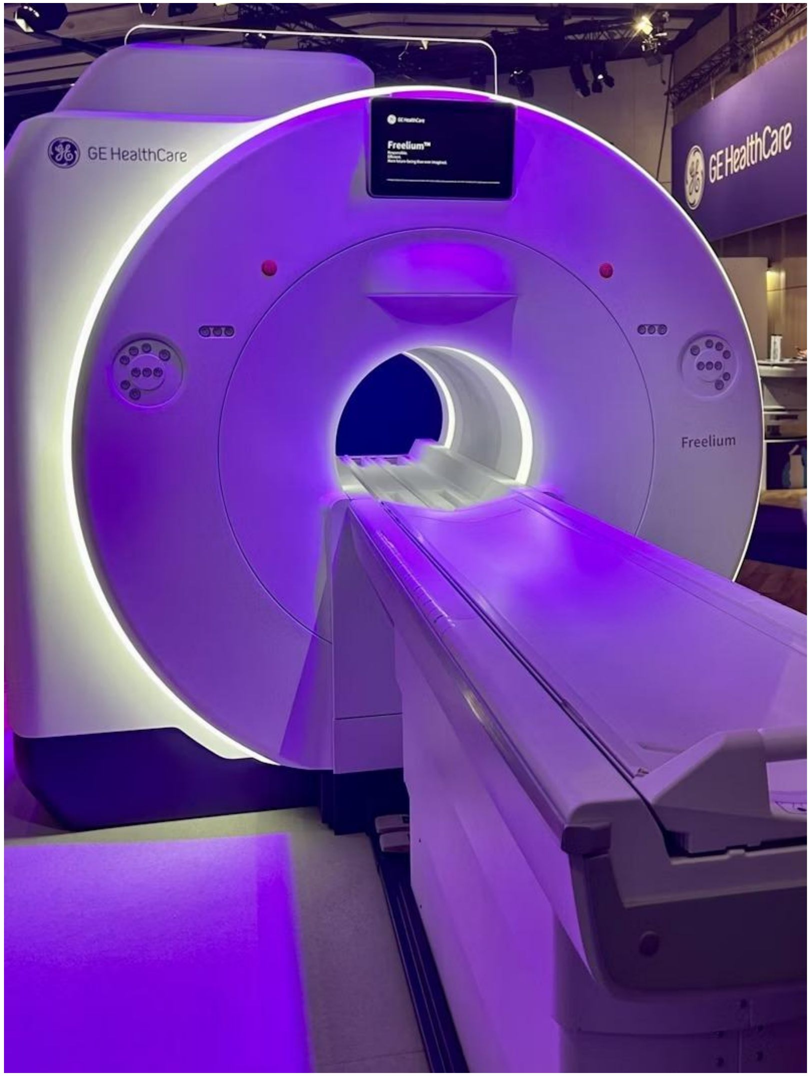


La piattaforma MAGNETOM Flow 1,5T senza elio[2] è basata sulla tecnologia DryCool. Con appena 0,7 litri di elio liquido, il magnete sigillato ha una struttura che non richiede alcun refill di elio. Si tratta di una soluzione realmente sostenibile che elimina la dipendenza dall'elio.

RM SIEMENS MAGNETOM FLOW

2024: il primo a Roma…

RM GE FREELIUM



VIENNA 2025 -- GE HealthCare (GEHC) is featuring its Freelium sealed MRI magnet Platform - Freelium is designed to enable MRI scanners to operate at less than 1% of the helium used in conventional magnet technology -- with no additional cooling or power requirements, according to the vendor. The new platform represents the evolution of GE HealthCare's Intelligent Platform Magnet (IPM) technology. Twenty sensors have been installed in Freelium to enable remote monitoring of the magnet, facilitating automated magnet protection and recovery -- without needing intervention by a field engineer, GE HealthCare said. What's more, it will be compatible with the firm's AI software. GE HealthCare's Freelium sealed MRI magnet platform. Freelium will be available in the near future, according to the vendor.

RM CANON (EX TOSHIBA)

Formazione per l'eccellenza

Canon MR: Cenni di Storia & Portfolio Prodotti

Formazione per l'eccellenza

Accettazione e Registrazione esame

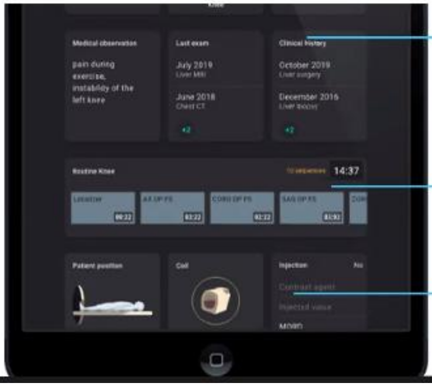
Sempre più vicini al paziente

WORKLIST PAZIENTE

Distretto esame, dati paziente.

AUTOVIEW

Visualizzazione immagini in acquisizione in tempo reale



STORICO ESAMI PAZIENTE

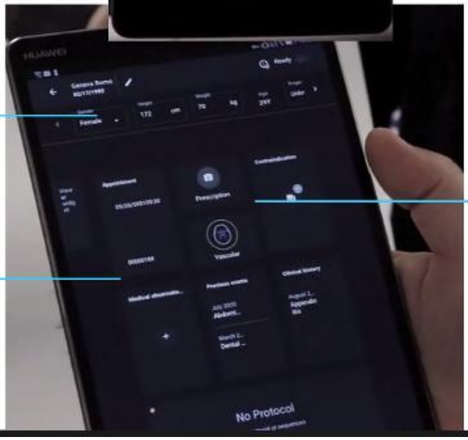
Visualizzazione esami precedenti

PROTOCOLLI

Selezione protocollo

STUDIO

Informazioni relative a bobine, posizione



DATI PAZIENTE

OSSERVAZIONI MEDICHE

Commenti e immagini

AREA COMMENTI

Configurablle

RM CANON (EX TOSHIBA)

Bobine

Al servizio del paziente e della clinica

Bobine per un elevato COMFORT PAZIENTE & un'elevata CONFIDENZA CLINICA

Bobine Dedicate

Bobine Flessibili

Bobine

Al servizio del paziente e della clinica

Shape Coils: LEGGERE, FLESSIBILI & VERSATILI

Bobine Shape Coils

https://www.nature.com/articles/d41586-018-07182-7

nature
International journal of science

NEWS FEATURE · 31 OCTOBER 2018

The world's strongest MRI machines are pushing human imaging to new limits

Researchers look to scanners with 10.5-tesla magnets and beyond for unprecedented detail about the brain.

RM SIEMENS 10.5T

RM SIEMENS 10.5T

The project was launched in 2008 with the aid of an $8 million grant from the U.S. National Institutes of Health (NIH). The magnet was built in the U.K. and shipped across the Atlantic Ocean and through the Great Lakes to Duluth, MN. It was then shipped over land on a specialized trailer to the CMRR building on the Twin Cities campus.

March 13, 2018 -- Researchers at the University of Minnesota's Center for Magnetic Resonance Research (CMRR) are breaking new ground by performing the first whole-body 10.5-tesla MRI scans on humans.

The scanner (Magnetom 10.5T, Siemens Healthineers) is able to image the entire body, but its main focus will be the brain.

RM SIEMENS 10.5T

Formazione per l'eccellenza

Magn Reson Med. 2019 Dec 17. doi: 10.1002/mrm.28131. [Epub ahead of print]

First in-vivo human imaging at 10.5T: Imaging the body at 447 MHz.

He X[1], Ertürk MA[1], Grant A[1], Wu X[1], Lagore RL[1], DelaBarre L[1], Eryaman Y[1], Adriany G[1], Auerbach EJ[1], Van de Moortele PF[1], Uğurbil K[1], Metzger GJ[1].

⊕ Author information

Abstract

PURPOSE: To investigate the feasibility of imaging the human torso and to evaluate the performance of several radiofrequency (RF) management strategies at 10.5T.

METHODS: Healthy volunteers were imaged on a 10.5T whole-body scanner in multiple target anatomies, including the prostate, hip, kidney, liver, and heart. Phase-only shimming and spoke pulses were used to demonstrate their performance in managing the $B_1^+|$ inhomogeneity present at 447 MHz. Imaging protocols included both qualitative and quantitative acquisitions to show the feasibility of imaging with different contrasts.

RESULTS: High-quality images were acquired and demonstrated excellent overall contrast and signal-to-noise ratio. The experimental results matched well with predictions and suggested good translational capabilities of the RF management strategies previously developed at 7T. Phase-only shimming provided increased efficiency, but showed pronounced limitations in homogeneity, demonstrating the need for the increased degrees of freedom made possible through single- and multispoke RF pulse design.

CONCLUSION: The first in-vivo human imaging was successfully performed at 10.5T using previously developed RF management strategies. Further improvement in RF coils, transmit chain, and full integration of parallel transmit functionality are needed to fully realize the benefits of 10.5T.

Doi: 10.1002/mrm.28131

RM SIEMENS MAGNETOM Free Max

Primo bore al mondo di 80 cm

High-V MRI…

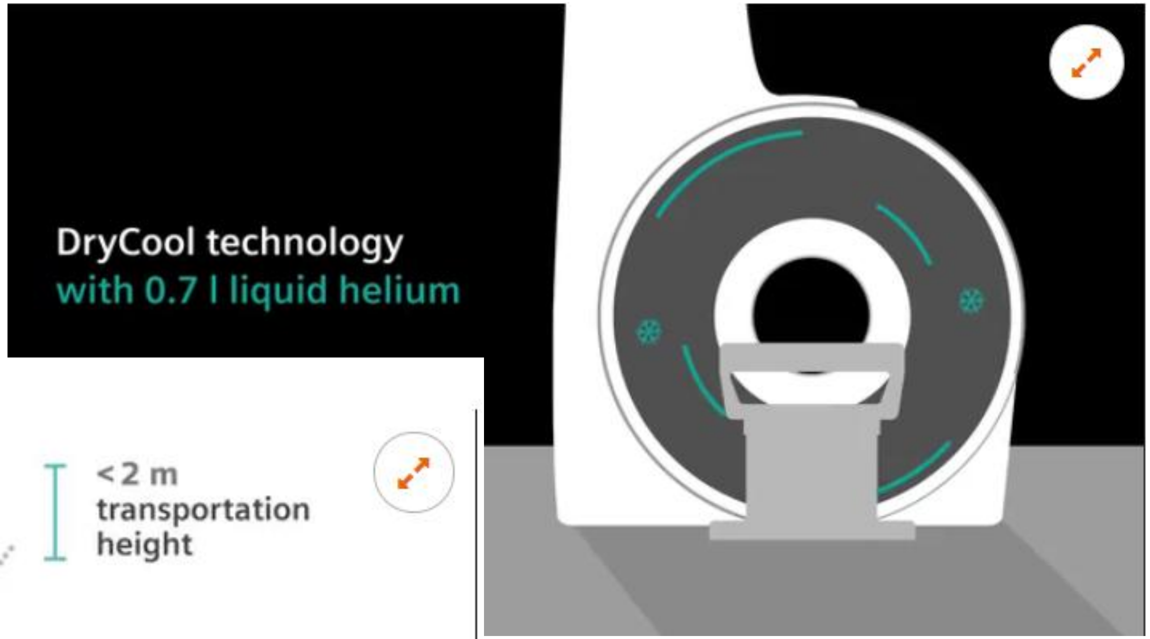
?

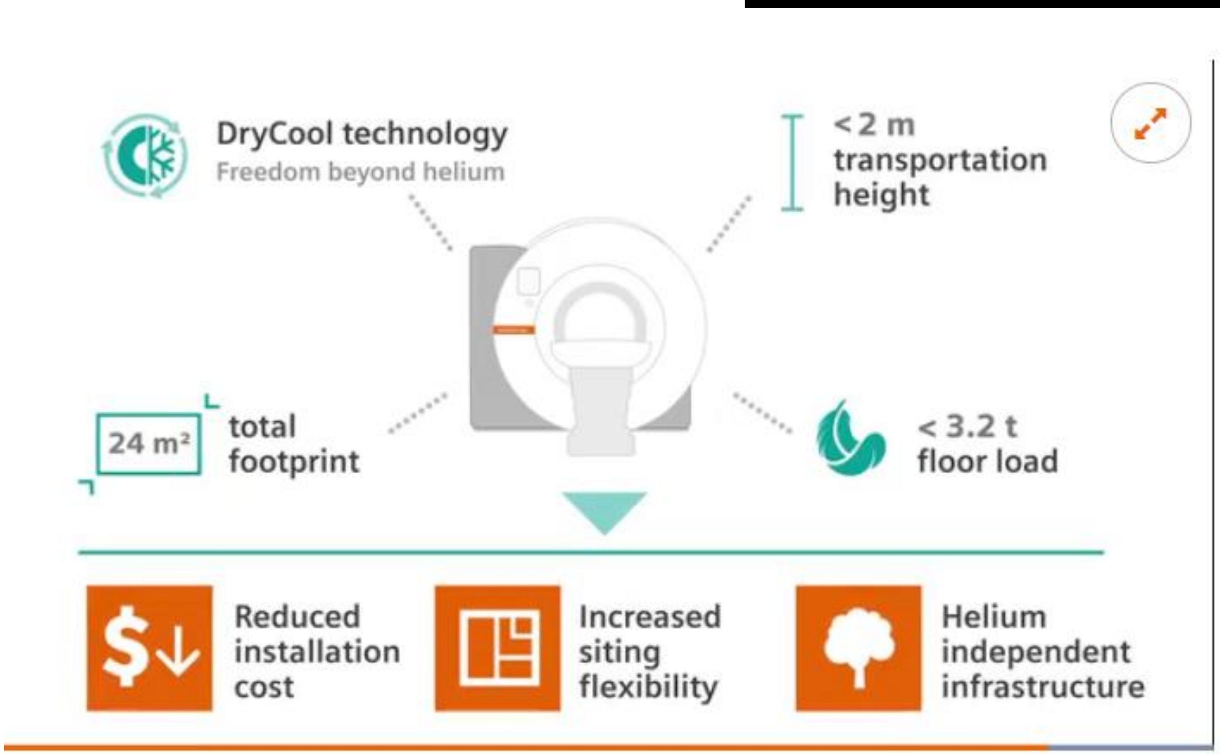
brand-new field strength of 0.55T…

RM SIEMENS MAGNETOM Free Max

Primo bore al mondo di 80 cm

RM SIEMENS MAGNETOM Free Max





Canon MR: Cenni di Storia & Portfolio Prodotti

CANON (Ex Toshiba)

Formazione per l'eccellenza

Bobine

Al servizio del paziente e della clinica

Bobine per un elevato COMFORT PAZIENTE & un'elevata CONFIDENZA CLINICA

Bobine Dedicate

Bobine Flessibili

Bobine

Al servizio del paziente e della clinica

Shape Coils: LEGGERE, FLESSIBILI & VERSATILI

Bobine Shape Coils

RM portatile

Formazione per l'eccellenza

https://hyperfine.io/

RM portatile

RM portatile

Formazione per l'eccellenza

Specifications

Height: 55" (140cm)

Width: 34" (86cm)

Power: 15A, 110V

Weight: 1,400lbs (630kg)

Hyperfine SWOOP

Main specs:

0.064T
630kg

61×31 cm

Permanent magnet/
Biplanar

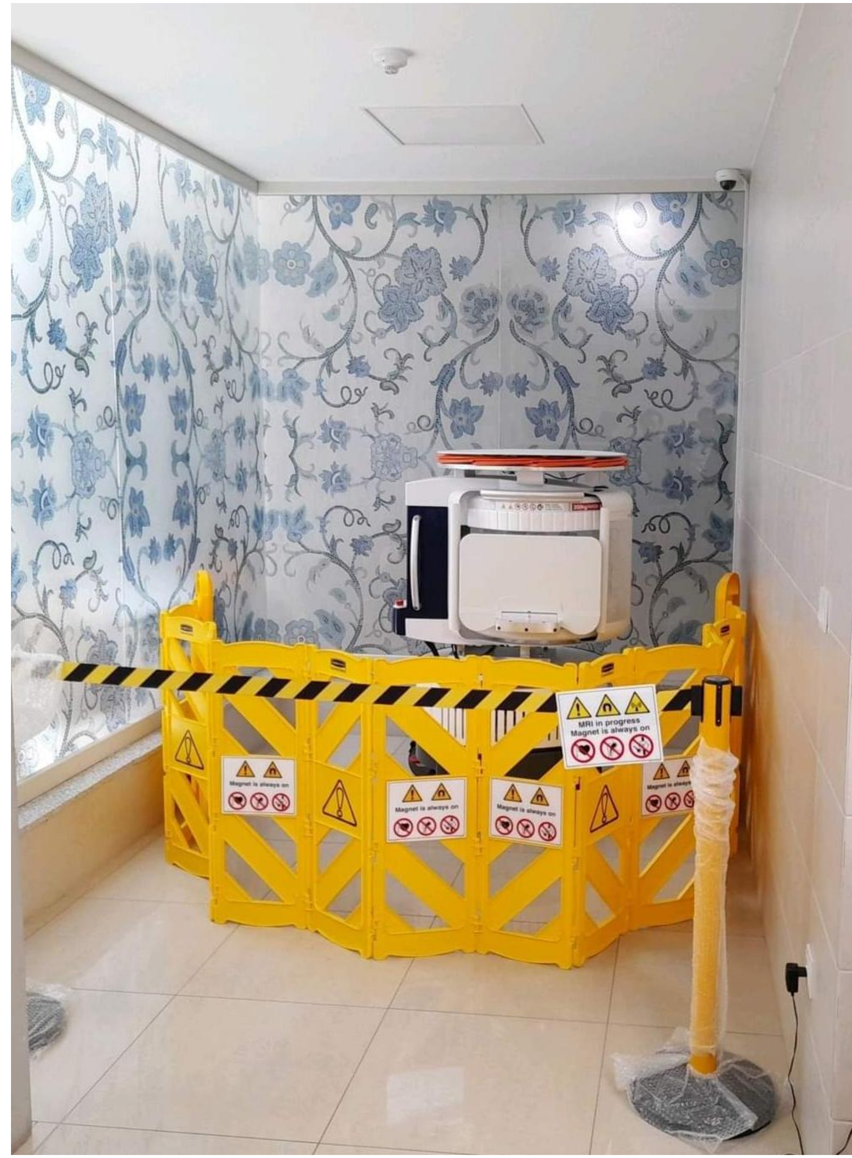
Plugs on 220V outlet

Cost:
$50,000 + monthly fee

RM portatile

RM portatile

Formazione per l'eccellenza



RM portatile

An RSNA attendee undergoes an MRI brain scan on the expo floor using the Hyperfine Swoop head MRI system. It is self-shields with a low field 0.064 T. It uses a standard wall power outlet and can be wheeled through a standard 34-inch wide door frame. It weighs 1,400 pounds. Imaging sequences include T1, T2, FLAIR, and DWI (with ADC map) and its operational controls are all directed on an iPad interface.

This is the second year the vendor has performed free MRIs on the show floor. The system is safe to operate outside a shielded room and around ferrous objects because of its built in shielding and low power magnet.

#RSNA22 RSNA

Formazione per l'eccellenza

Jamal

ULF MRI Set-Up and Scan Protocol

Typical Positioning for ICU Patient

Scan protocol (30 min):

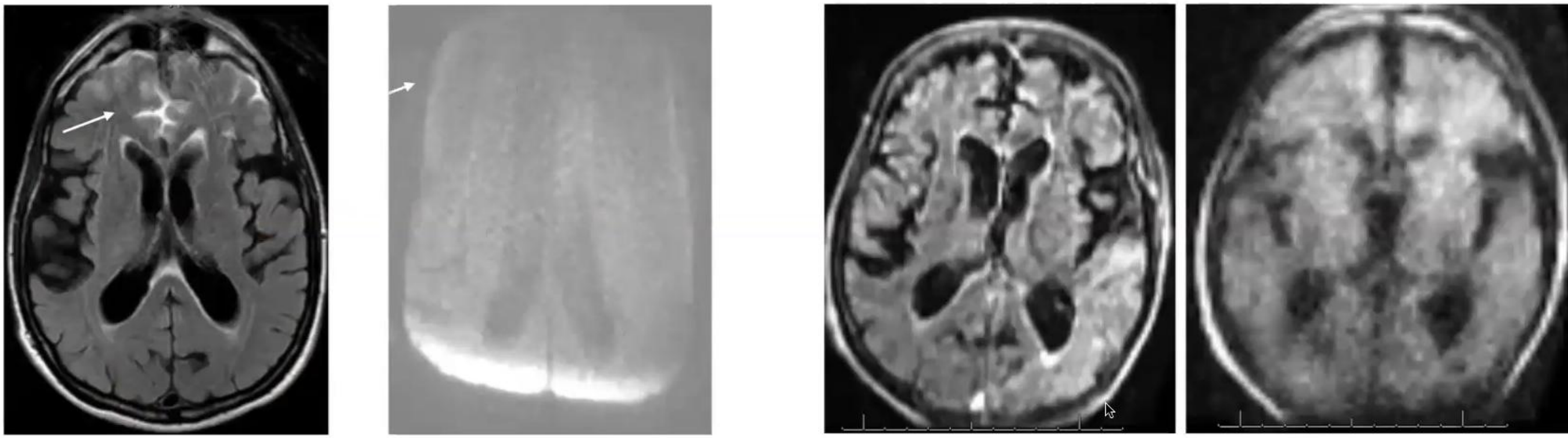
- Localizer
- Fast Axial T2 (2:10)
- Axial and Coronal FLAIR (7:50 each)
- Sagittal T1 weighted (4:00)
- Axial DWI with ADC map (8:40)

Susceptibility Artifact Reduction

Jamal Derakhs

1.5T — FLAIR, DWI

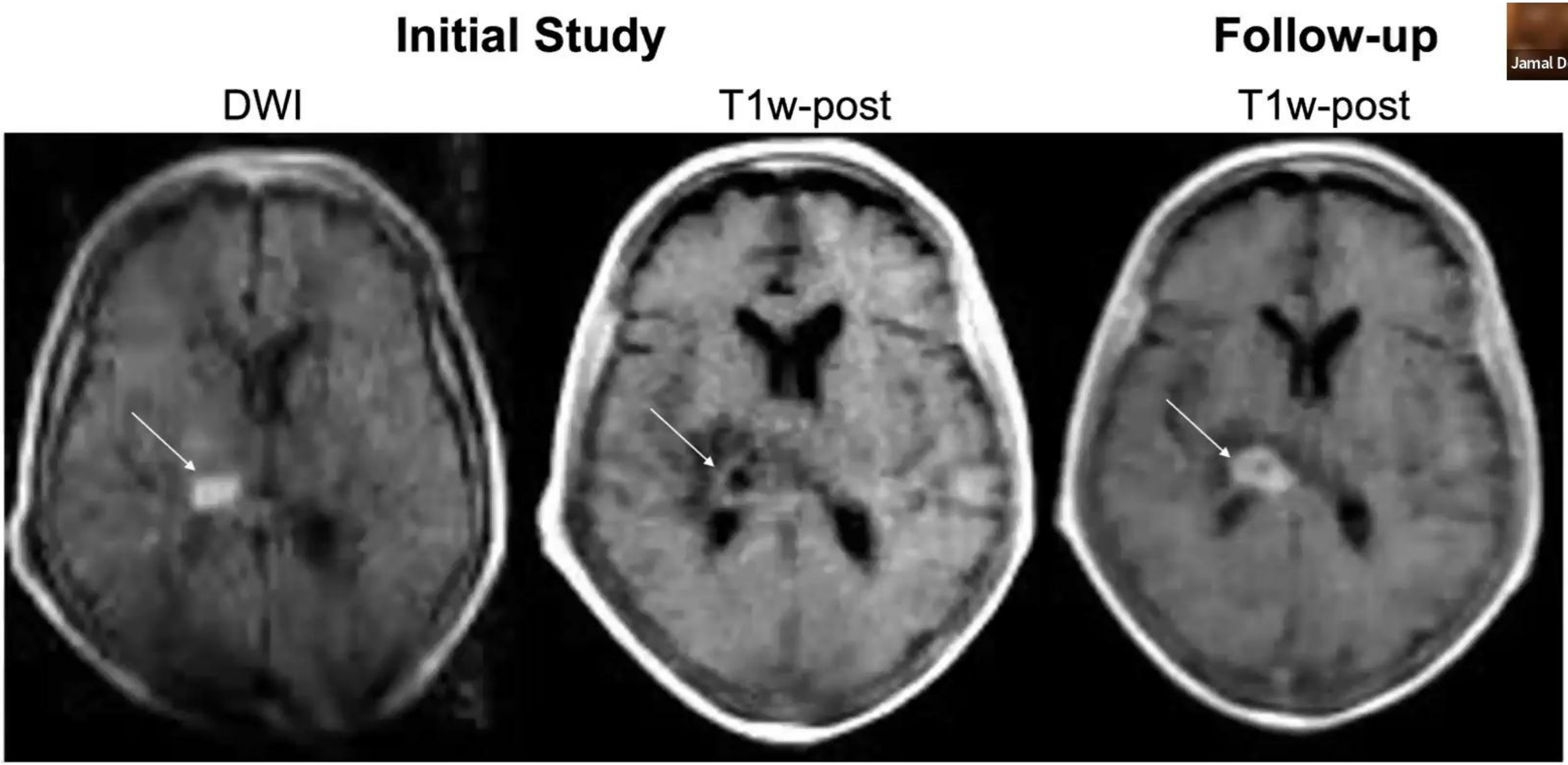
0.064T — FLAIR, DWI



- 1.5T scan was nondiagnostic due to susceptibility artifact
  - Lack of FLAIR suppression in frontal sulci
  - Severe signal loss and geometric distortion on DWI
- 0.064T MRI was diagnostic with elimination of artifacts

17

RM portatile



- 102% enhancement in the right thalamic abscess
- Contrast enhancement previously thought to not be poorly visualized

18

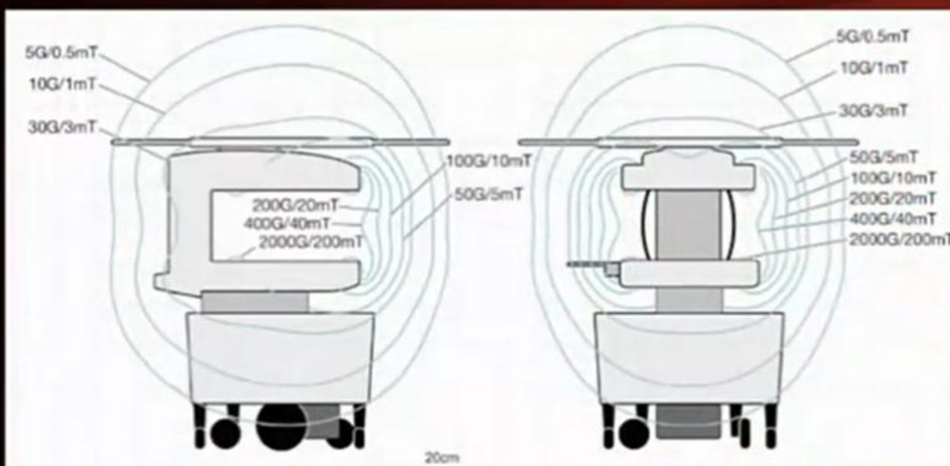
RM portatile

Formazione per l'eccellenza

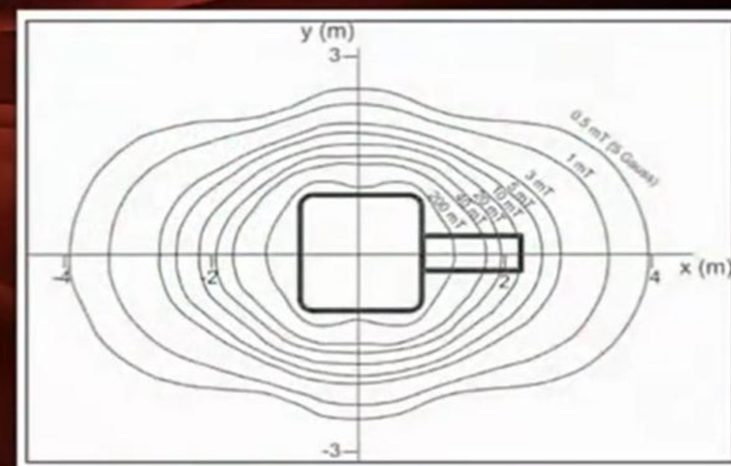
Magnetic Fringe Field
Swoop® System vs. Conventional MR System

Static Magnetic Field

- Projectile injuries, fatalities, and scanner damage



Swoop Portable MR Imaging System, 0.064-T, SFG-7 T/m



Conventional 1.5-T MR System, SFG ≤1,200 T/m

Formazione per l'eccellenza

Hyperfine secures CE marking for Swoop portable MRI system

nov 2024

Connecticut-based company Hyperfine has secured CE marking under the European Medical Device Regulation for its Swoop portable brain MRI system.

The company in 2023 secured initial CE certification for the Swoop system. Hyperfine said this latest approval will help position the company to launch the system broadly across Europe. Hyperfine in 2024 expanded its global distribution network with partnerships established in 13 European countries, including the five major European markets.

RM 11.7T

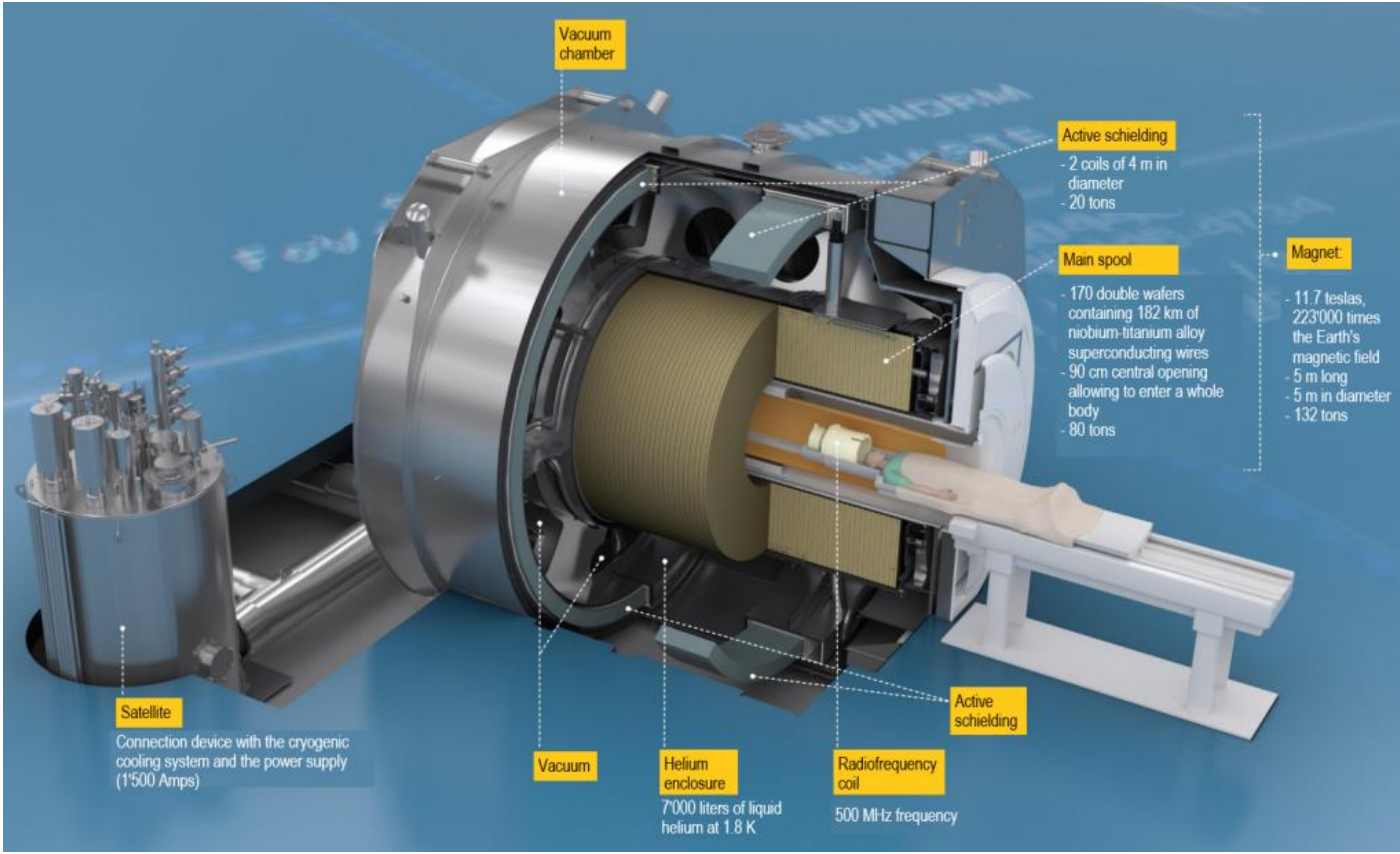
Formazione per l'eccellenza

Metrolab
Magnetic precision has a name

https://www.metrolab.com/it/gigantic-11-7-t-mri-magnet-iseult-a-discussion-with-lionel-quettier/

RM 11.7T

Magnetic precision has a name



Metrolab

Magnetic precision has a name

Formazione per l'eccellenza

Metrolab: What is the significance of the 90 cm opening?

Dr. Quettier: The MRI scanner is much more than just a magnet. The larger aperture gives more room for equipment to be positioned inside the bore but situated away from the field of interest: this reduces the risk of interference. For example, we need gradient coils to generate pulsed fields and to measure the Nuclear Magnetic Resonance (NMR). The gradient coils need to be far away from the magnet coils to limit magnetic coupling, which would corrupt the results. Other projects in Korea and the United States, which are also operating at 11.7 T, have a central bore of only 68 cm. The larger bore opens the possibility to image not only the brain but also any other part of the body.

RM 11.7T

Figure: Front view of the magnet after installation in Saclay, France. © Francis Rhodes/CEA

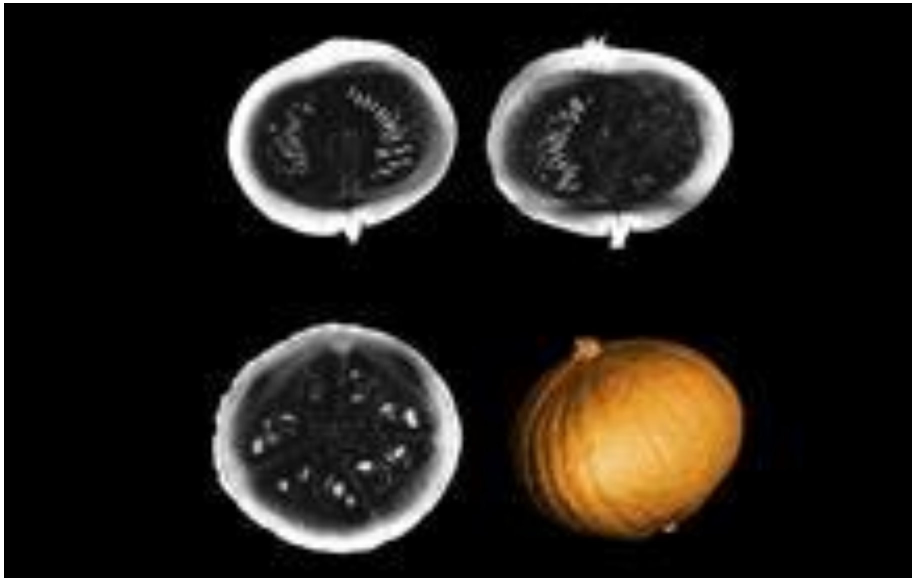
Formazione per l'eccellenza

Metrolab
Magnetic precision has a name

September 2021, the 11.7 Tesla MRI of the Iseult project, the most powerful in the world for human imaging, has just unveiled its first images. They validate the entire process that has enabled, thanks to multiple technological breakthroughs, the transformation of an « outstanding » magnet, delivered in 2017 to the CEA-Paris-Saclay site, into an « imager ». This MRI, designed by CEA engineers and researchers together with Siemens Healthineers, will enable major advances in fundamental research, cognitive sciences and in understanding brain pathologies.

RM 11.7T – LA ZUCCA …

The most powerful MRI scanner in the world delivers its first images!

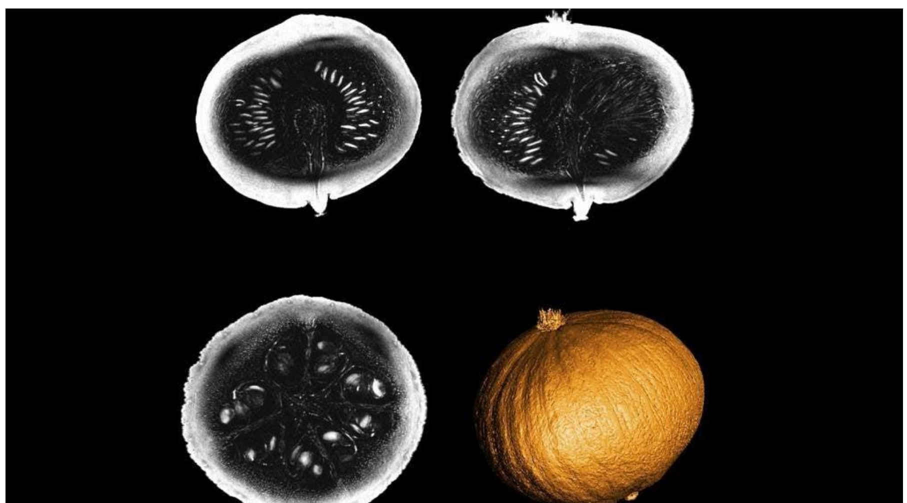


September 2021

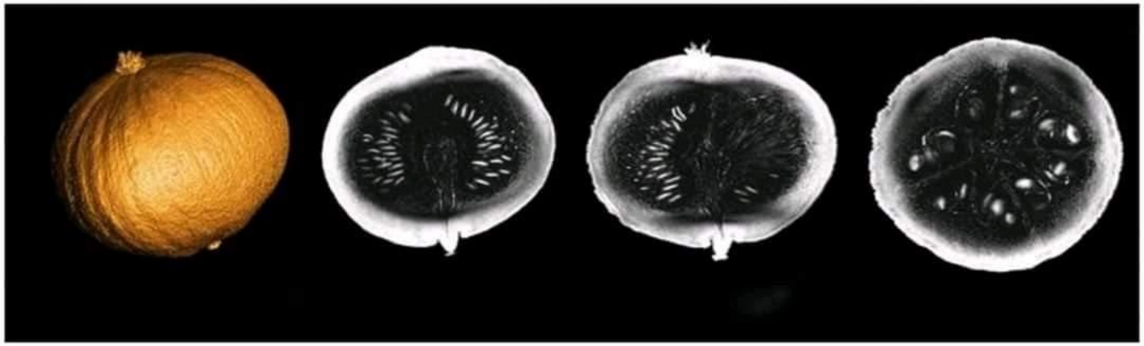
Magnetic precision has a name

A **pumpkin**: this unusual object was chosen for its multiple textures by CEA engineers and researchers to make the first images with the world's most powerful 11.7 T human whole-body MRI of the Iseult project, installed at NeuroSpin at CEA-Paris-Saclay.

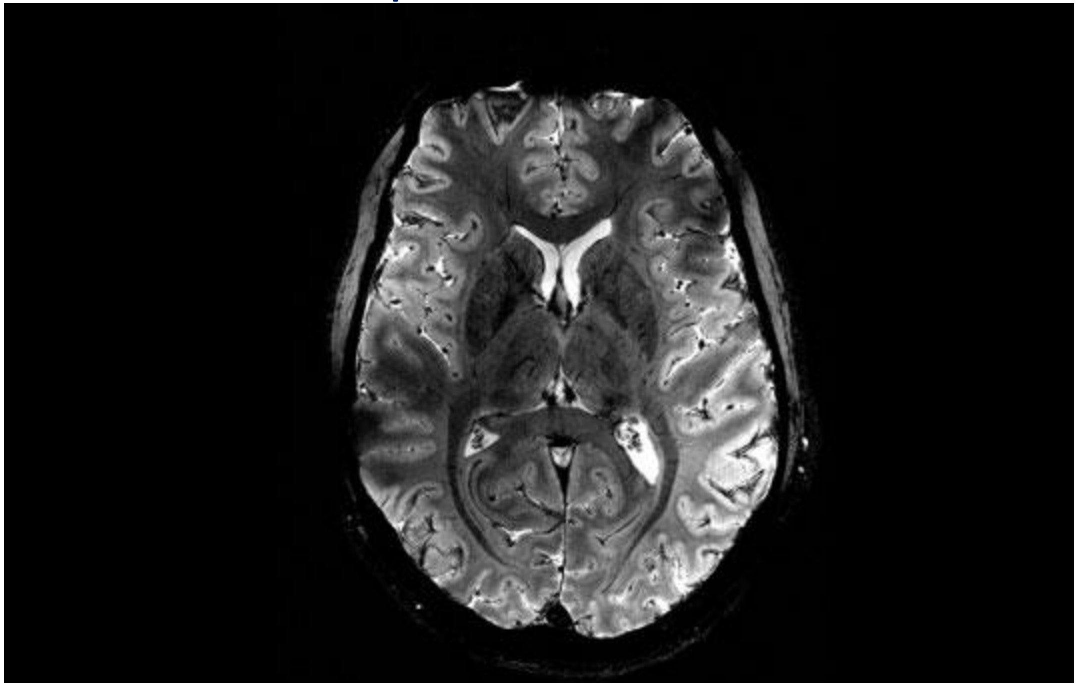
With a resolution of 400 microns in three dimensions, the images of the cucurbit prefigure the prowess that the scientific and technical teams of the CEA and their partners will be able to achieve in order to probe the human brain, for the benefit of fundamental research, cognitive sciences and in understanding brain pathologies. These first acquisitions validate the entire process that has made it possible, thanks to multiple technological breakthroughs, to transform an "outstanding" magnet into an MRI machine.




ISEULT MAGNETOM 11.7T MRI
cea
SIEMENS Healthineers

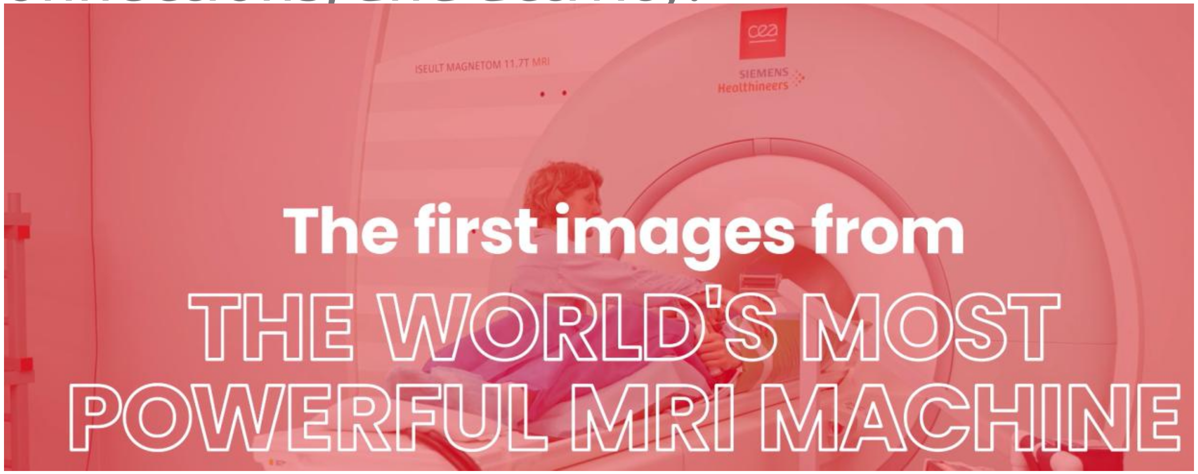


https://www.cea.fr/english/Pages/News/world-premiere-living-brain-imaged-with-unrivaled-clarity-thanks-to-world-most-powerful-MRI-machine.aspx



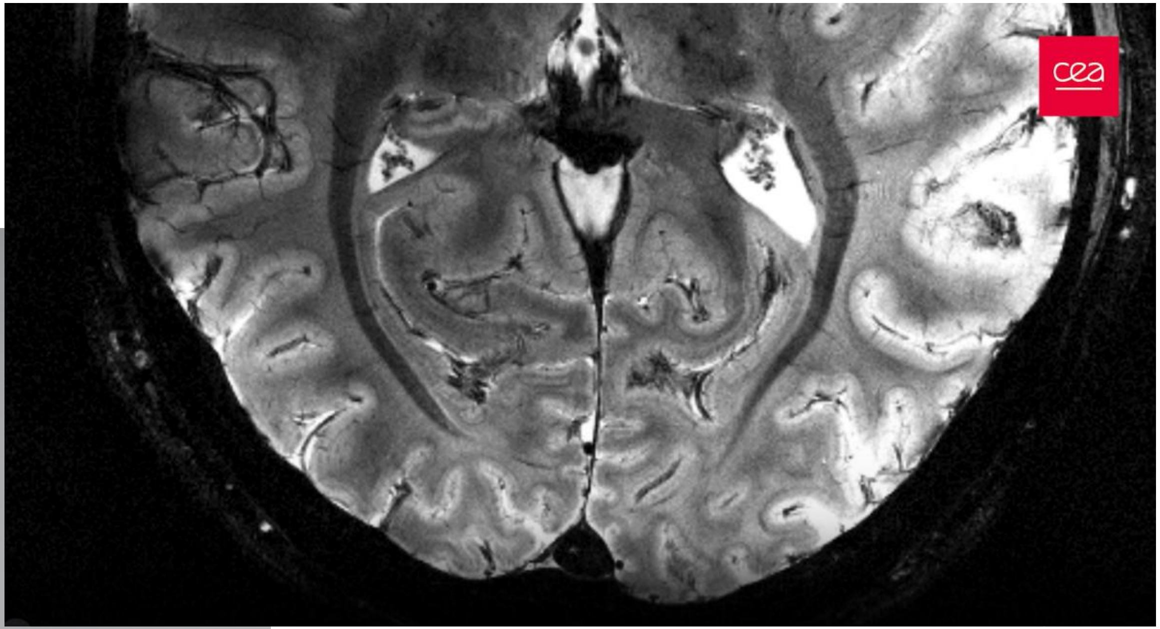
A world premiere: the living brain imaged with unrivaled clarity thanks to the world's most powerful MRI machine

The CEA is revealing a series of in vivo human brain images acquired with the Iseult MRI machine and its unmatched 11.7 teslas magnetic field strength. This success is the fruit of more than 20 years of R&D as part of the Iseult project, with one pillar goal being to design and build the world's most powerful MRI machine. Its ambition is to study healthy and diseased human brains with an unprecedented resolution, allowing us to discover new details relating to the brain's anatomy, connections, and activity.



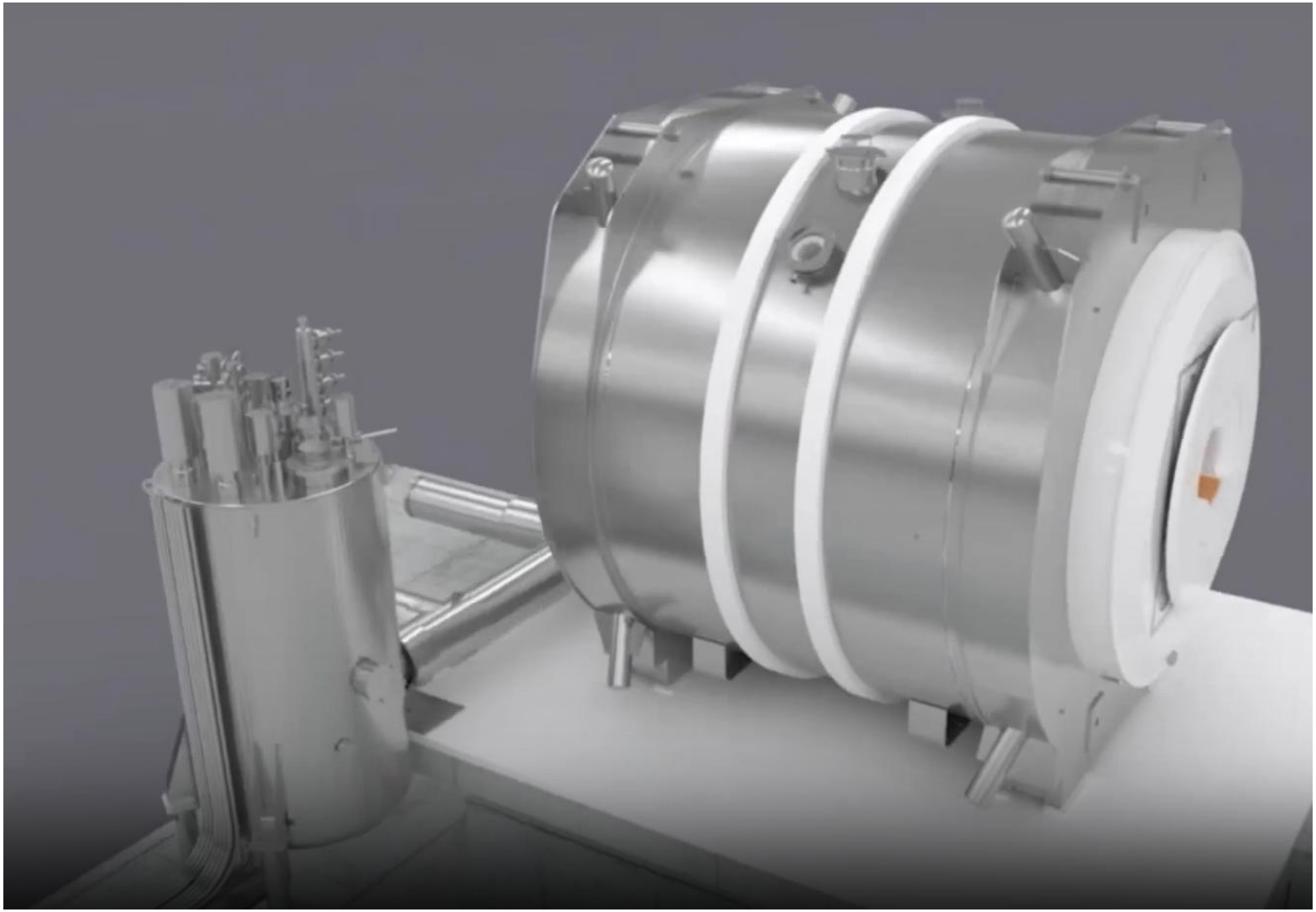
Metrolab
Magnetic precision has a name

Formazione per l'eccellenza



Gemelli

WORLD'S BEST HOSPITALS 2025 Newsweek statista




cea
3


1,7T MRI

Key figures

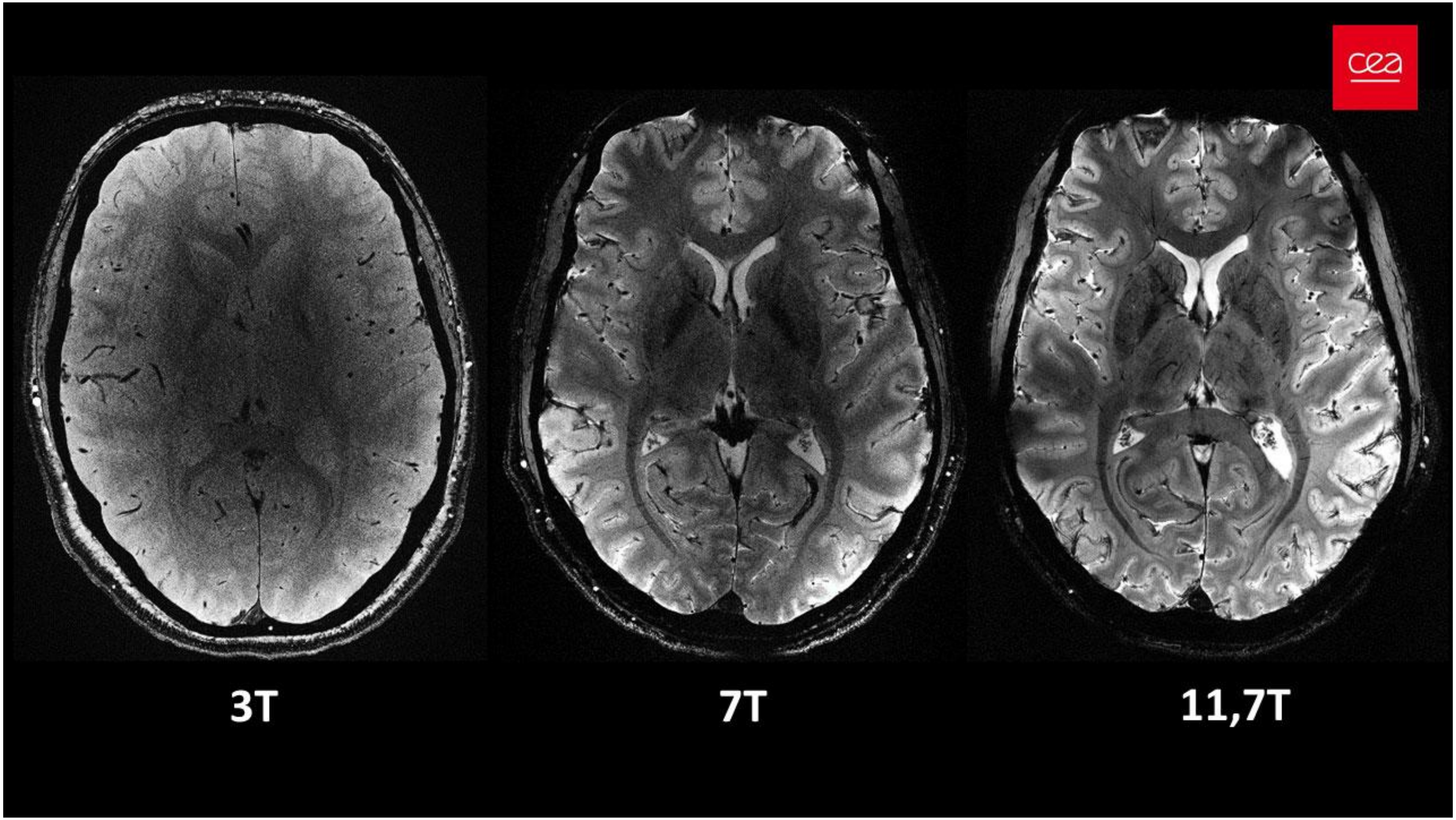
- 11,7 teslas (T) magnetic field strength (vs 1.5 and 3 T for conventional MRI machines in hospitals)
- 132 tons, 5 m long and 5 m wide
- 182 km of superconducting wires
- 1 500 amperes running through the coil
- -271.35 °C: the temperature at which the magnet is cooled by using 7 500 litres of liquid helium
- 90 cm of central opening

RM 11.7T

Aprile 2024

METROLAB
Magnetic precision has a name

Formazione per l'eccellenza



Gemelli

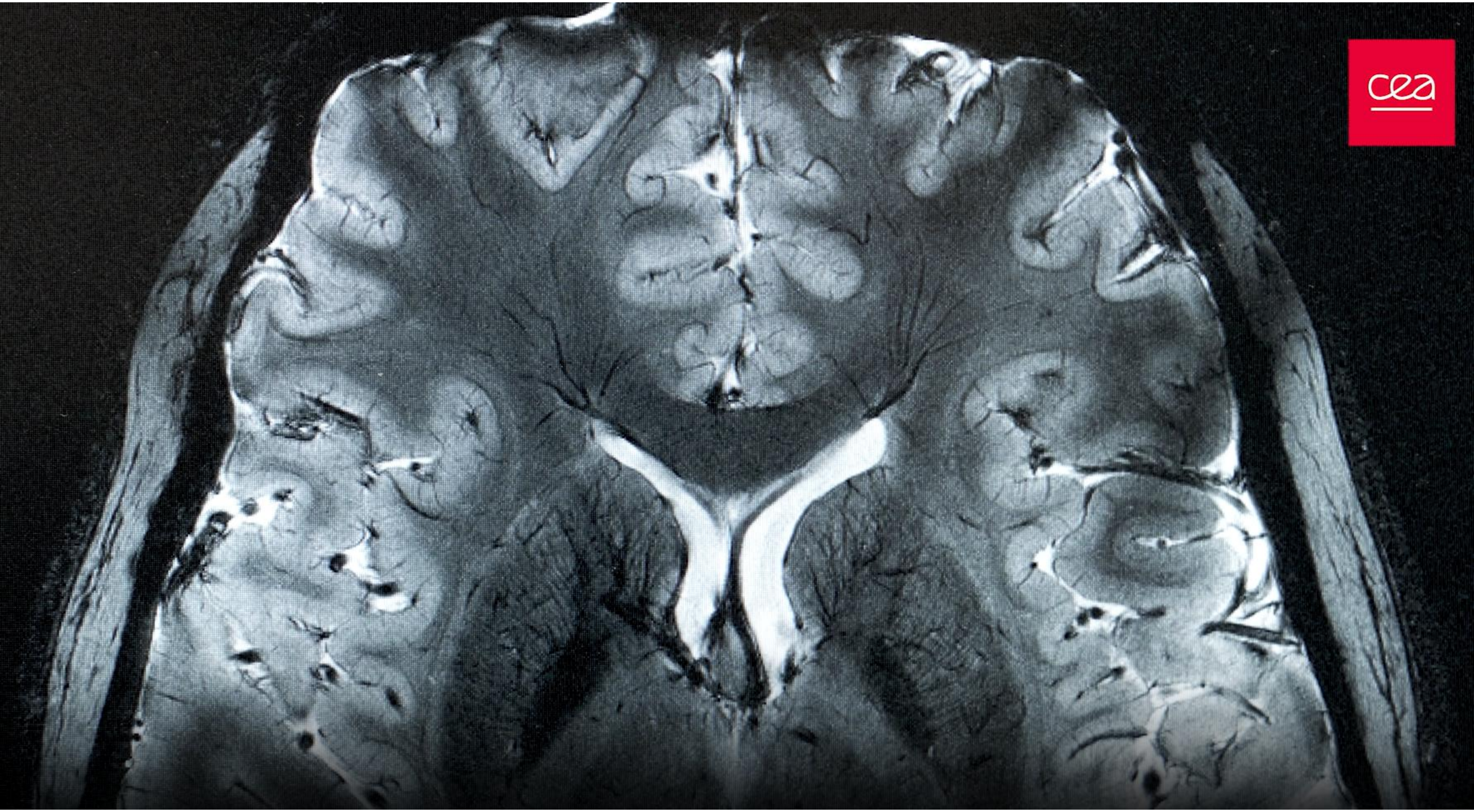
WORLD'S BEST HOSPITALS 2025 Newsweek statista

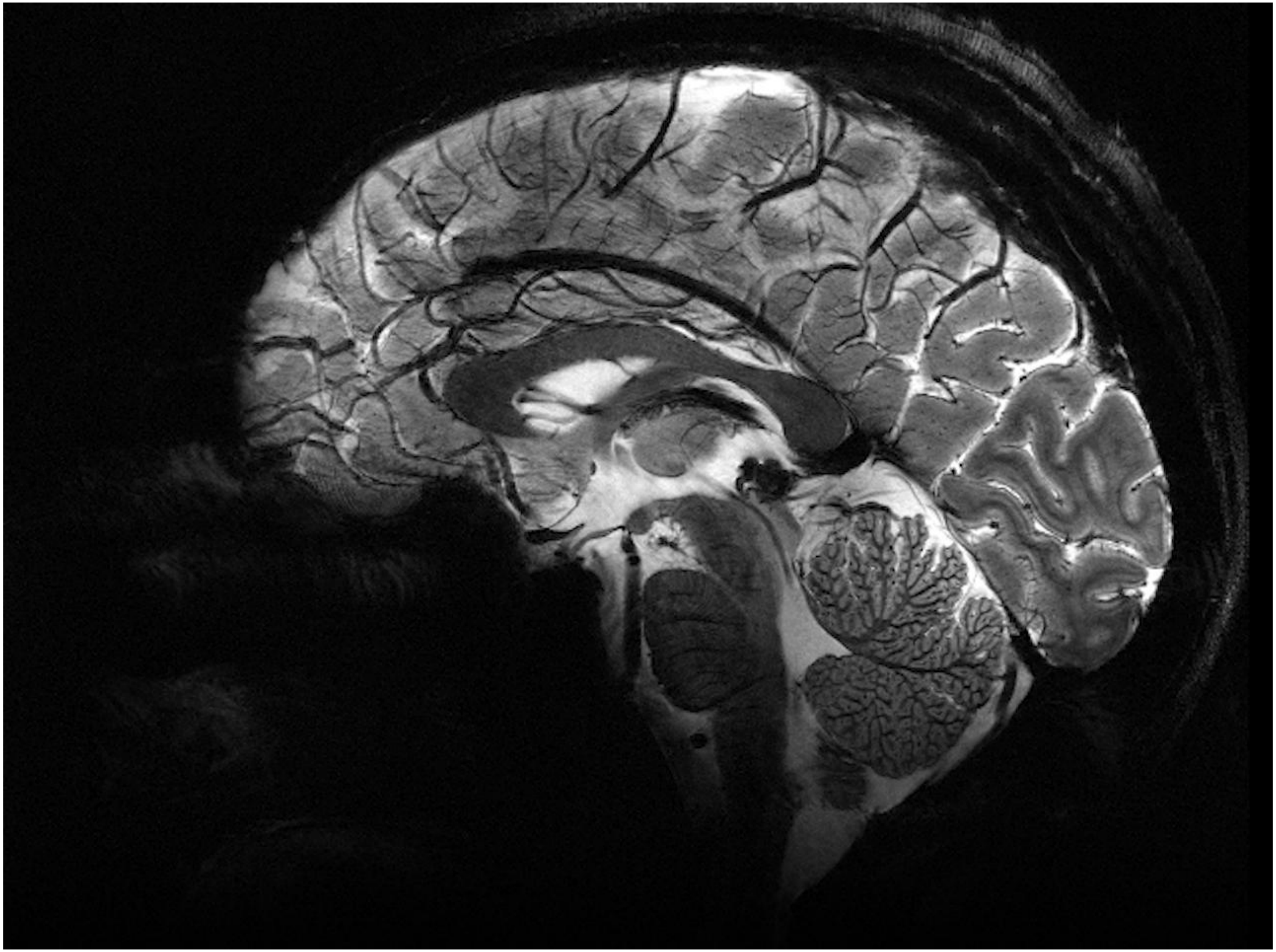
RM 11.7T

Aprile 2024

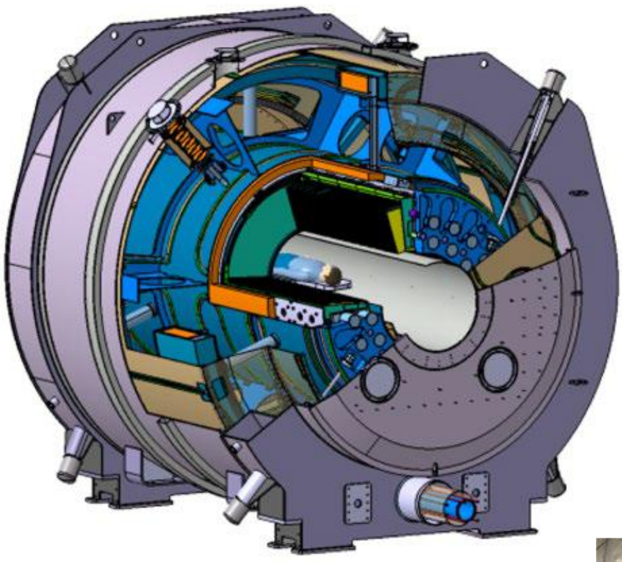
Magnetic precision has a name

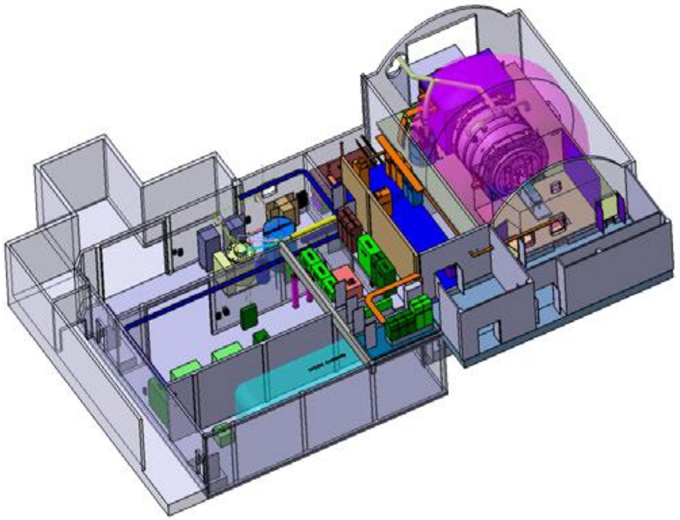
Formazione per l'eccellenza

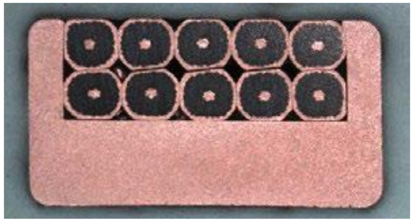




RM 11.7T







https://www.nature.com/articles/s41592-024-02472-7

RM 11.7T

https://www.nature.com/articles/s41592-024-02472-7

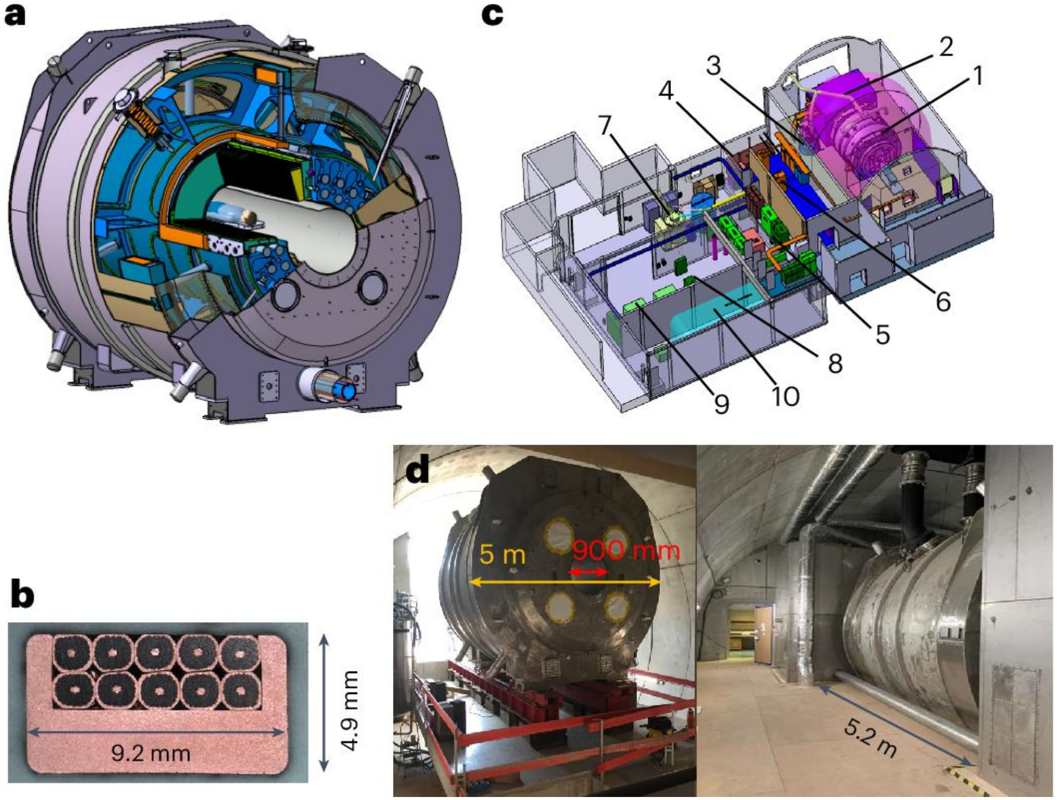
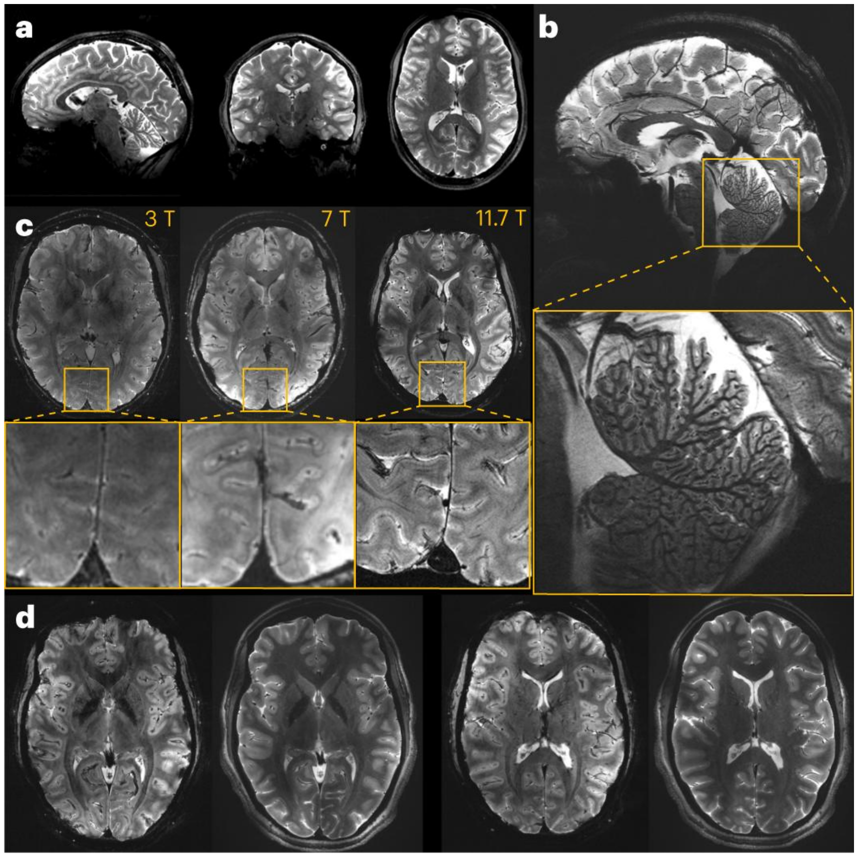


Fig. 1 | Iseult magnet and installation set-up. a, Schematic of the magnet showing the main coil and the two actively shielding coils. The magnet weighs
132 tons, has an outer diameter and total length of just under 5 m and the bore diameter is 90 cm. **b**, Cross-section of the wire used for the magnet showing the packing of the ten strands of NbTi-Cu wire within a copper channel.
c, General view of the Iseult MRI inside the NeuroSpin building: (1) magnet (2), Faraday cages, (3) satellite, (4) dump resistor, (5) magnet control command and power convertor, (6) Siemens Healthineers MRI equipment, (7) helium liquefier, (8) helium pumps, (9) compressors and (10) helium balloon. **d**, Left: initial installation of the magnet within a dedicated arch (10 m in diameter) at
NeuroSpin. Right: current side view of the magnet within the arch, extending above the ceiling and under the floor of the patient side room, going all the way in the back of the arch.

RM 11.7T

https://www.nature.com/articles/s41592-024-02472-7



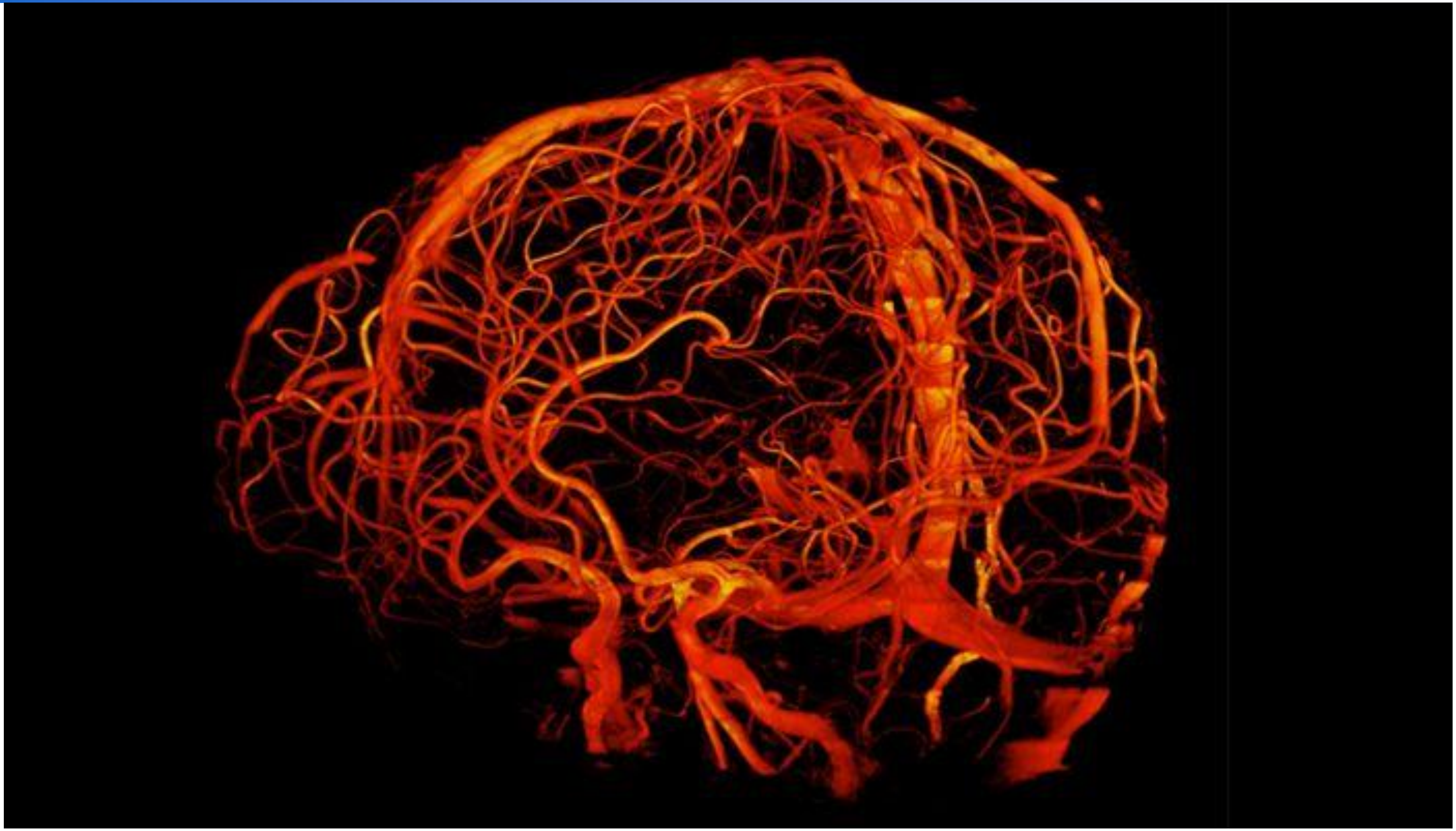
a, In vivo 3D T_2 variable flip angle turbo spin-echo acquisition at 11.7 T with parallel transmission GRAPE universal pulses (resolution 0.55 × 0.55 × 0.55 mm^3, acquisition time 13 min) demonstrating the high B_1^+ (RF) field homogeneity reached throughout the whole brain volume. **b**, In vivo T_2^*-weighted 2D GRE sagittal slice (resolution 0.2 × 0.2 × 1 mm^3, acquisition time 8 min 30 s). **c**, T_2* weighted 2D GRE axial images acquired at 3 T (left), 7 T (middle) and 11.7 T (right) with identical acquisition times (4 min 17 s), while keeping similar contrast-to-noise ratio through adjusted acquisition parameters (FA (°), TR (ms) and TE (ms) of 27, 750 and 45; 34, 950 and 25; 27, 600 and 20 at 3, 7 and 11.7 T, respectively) and spatial resolution (0.5, 0.325 and 0.2-mm in-plane resolution for 3, 7 and 11.7 T, respectively, 1-mm thickness). **d**, The 11.7 T T_2^*-weighted 2D GRE axial images (resolution 0.19 × 0.19 × 1 mm^3, acquisition time 5 min 16 s) juxtaposed to turbo spin-echo T_2-weighted images (resolution 0.3 × 0.3 × 1 mm^3, acquisition time 4 min 26 s).

Pratica: RM presente e futuro

https://www.nature.com/articles/d41586-018-07182-7

The amount of heating generated by such machines could be even more problematic. Some researchers have speculated that scanners operating above 14 T could also cause nerve conductance to slow down, stimulate peripheral nerves or damage DNA, although Schepkin says he has seen none of these effects so far in animals, even at 21.1 T. Still, Scheffler thinks that at some point there will be a limit to field strength beyond which we can't go without damaging the body: "I don't think we can go higher and higher forever."

Pratica: RM 7T

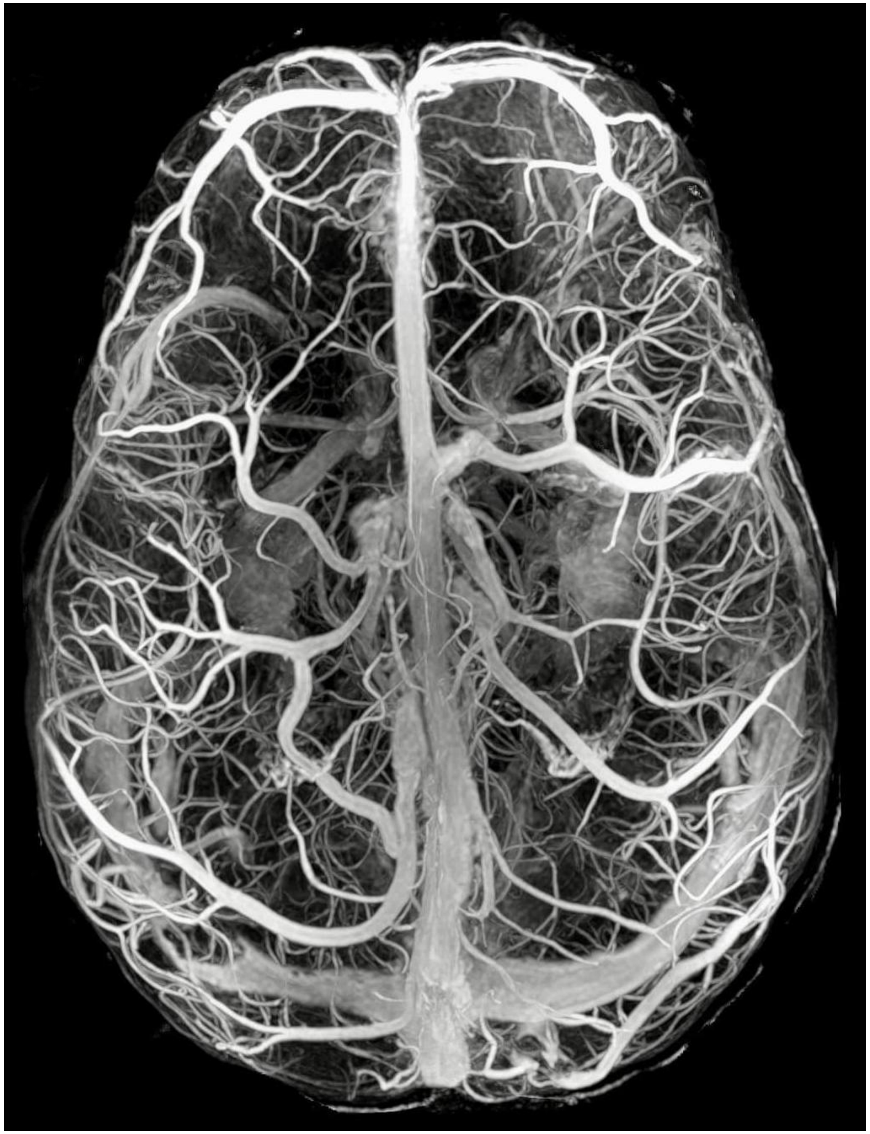


Cerebral blood vessels glow orange in this picture, generated by a 7-tesla magnetic resonance imaging scanner at The University of Queensland in Australia. Credit: Centre for Advanced Imaging, The University of Queensland

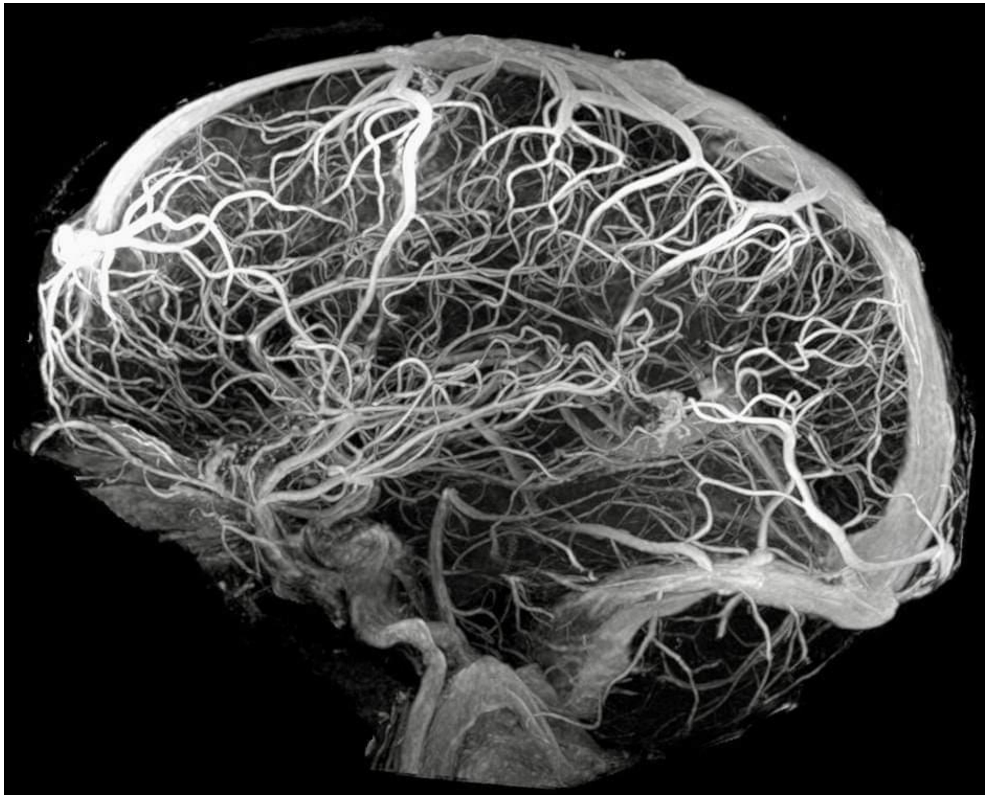
CE-MRV 7T

Contrast-Enhanced Magnetic Resonance Venography (CE-MRV) of the brain at 7T, Siemens MAGNETOM Terra.

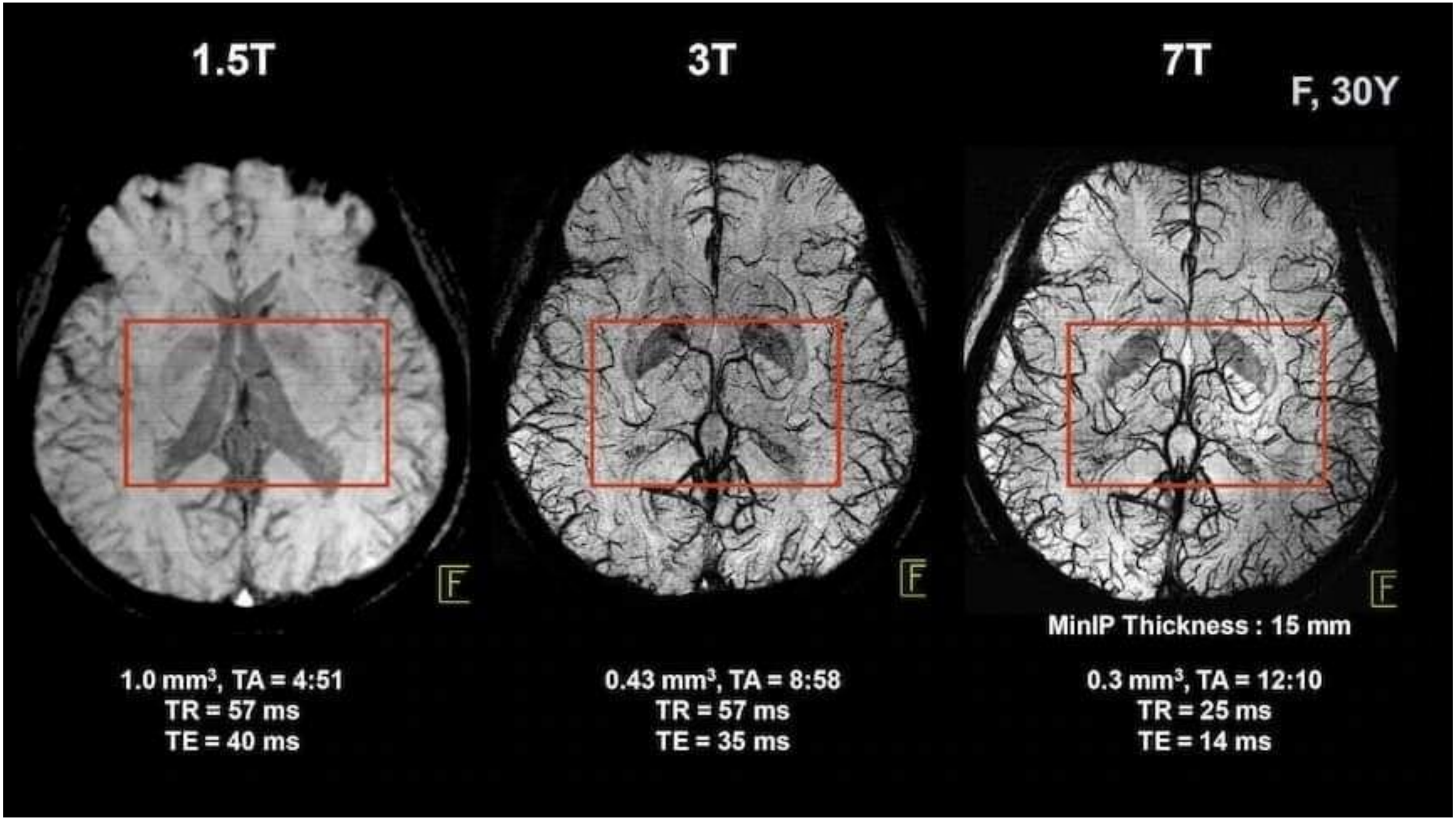
300 micron isotropic resolution!



CE-MRV 7T



SWI


1.5T
3T
7T
F, 30Y
MinIP Thickness : 15 mm
1.0 mm³, TA = 4:51
TR = 57 ms
TE = 40 ms
0.43 mm³, TA = 8:58
TR = 57 ms
TE = 35 ms
0.3 mm³, TA = 12:10
TR = 25 ms
TE = 14 ms

7T

7T scanners on the market

Siemens Healthineers
MAGNETOM® Terra.X

GE Healthcare
SIGNA™ 7.0T

University of Zurich

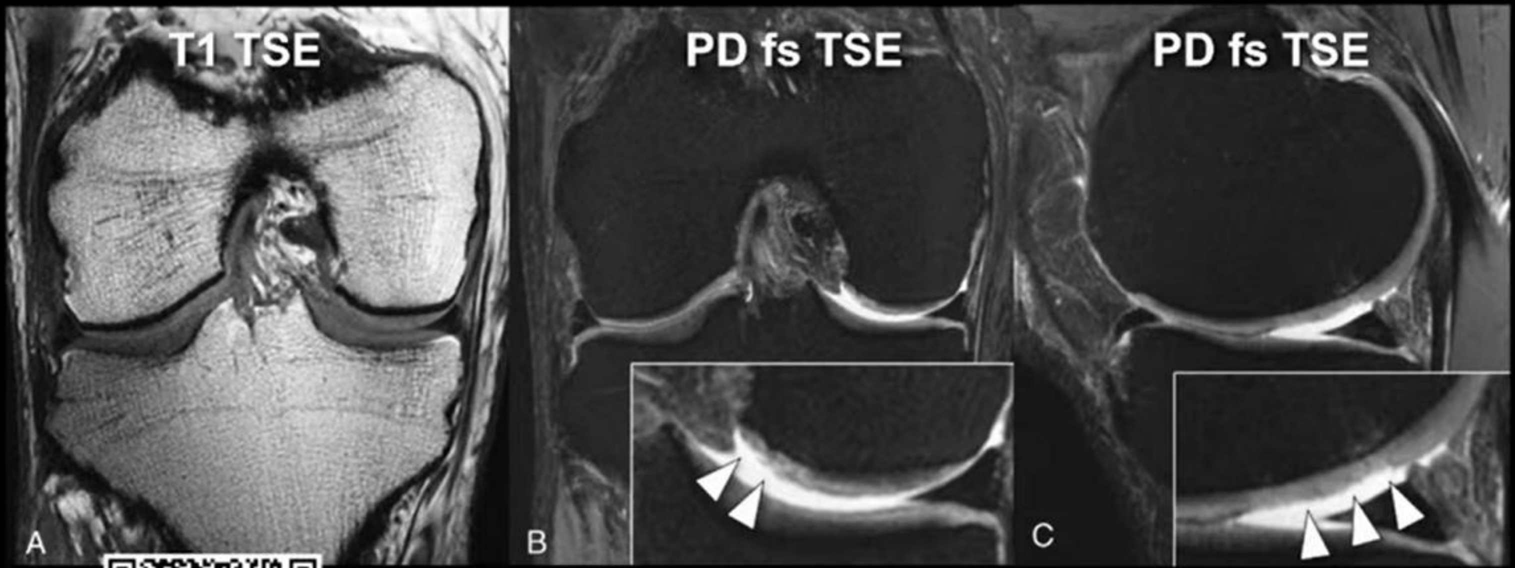
Balgrist

7T


Installation
7T MRI
in 2018
University of Zurich
balgristcampus
SWISS CENTER FOR
Musculoskeletal Imaging
Balgrist

Formazione per l'eccellenza

High resolution 7T MRI: Femorotibial



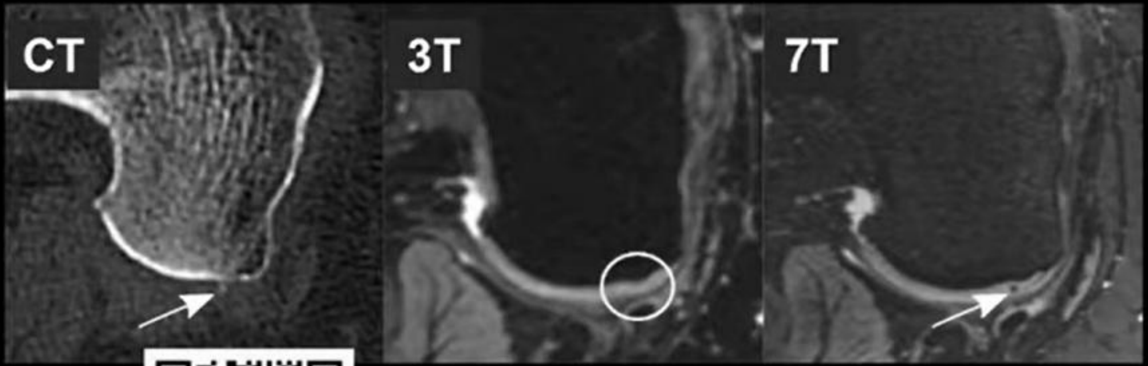
SCAN ME!
#OpenAccess

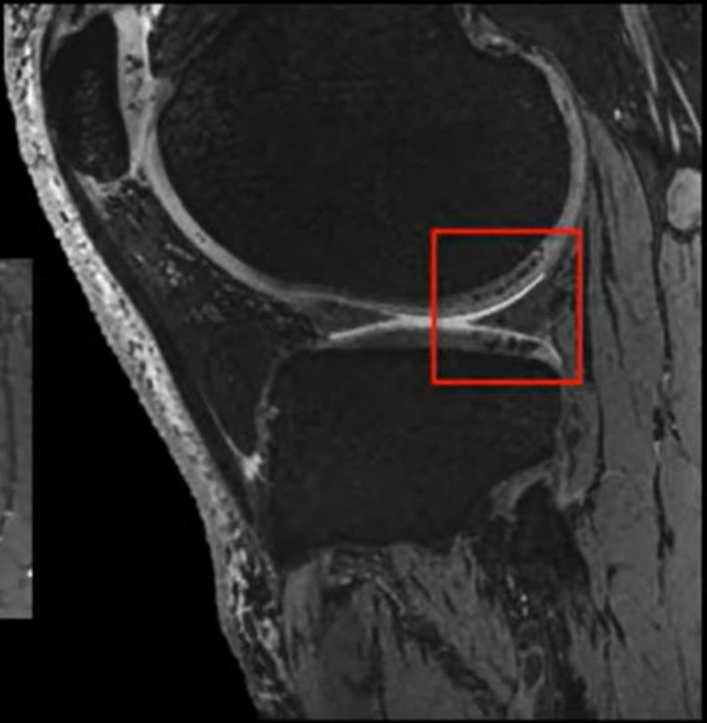
Pazahr S, Nanz D, Sutter R. Invest Radiol. 2023; 58(1):88-98.

Balgrist

7T DESS: Superior depiction of chondrocalcinosis

7T superior to 3T at detection of small calcifications in articular cartilage and menisci, and may be even superior to CT



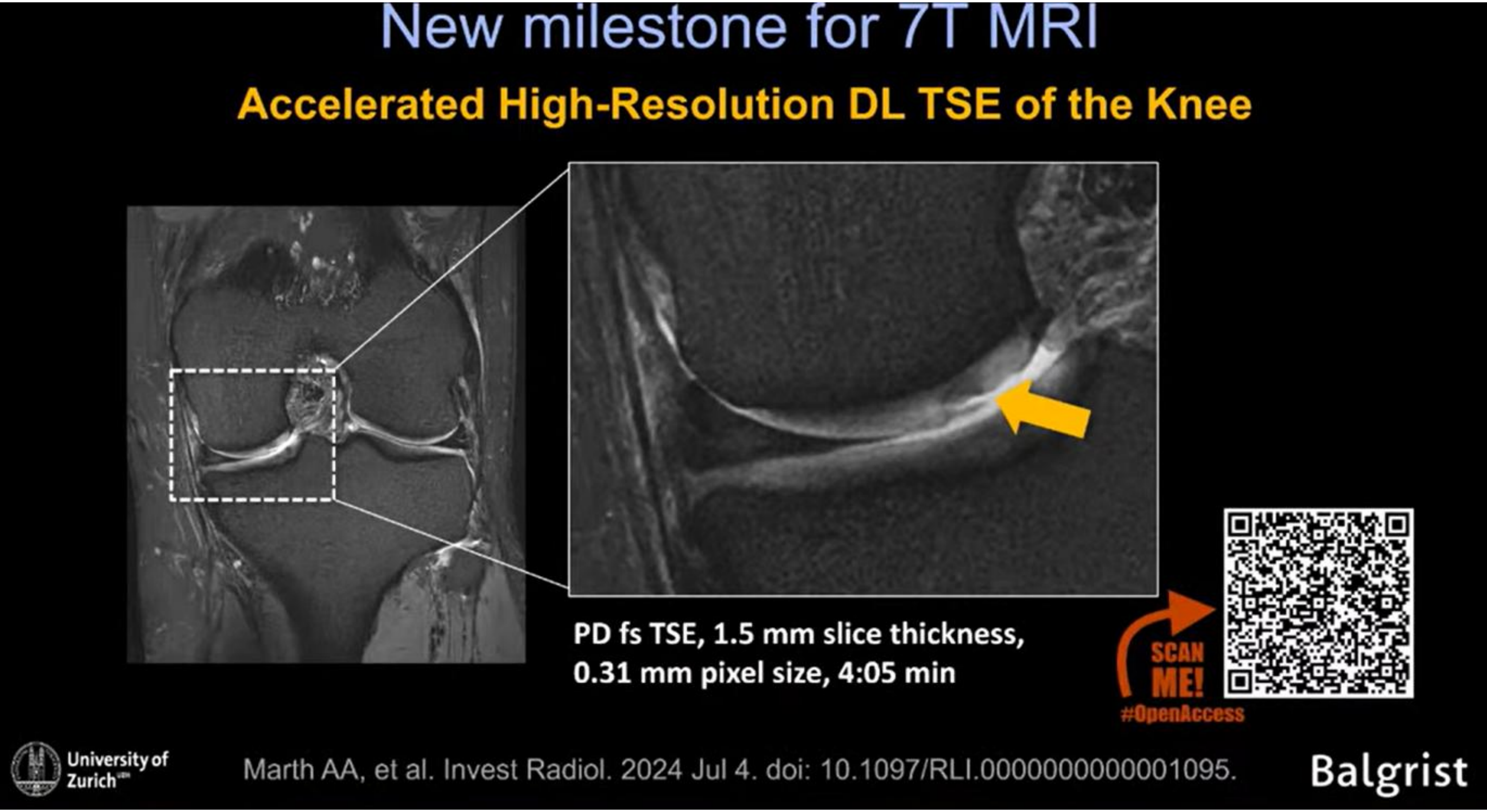


SCAN ME!
#OpenAccess

Germann C, et al. Eur Radiol 2021;31(12):9436-9445.

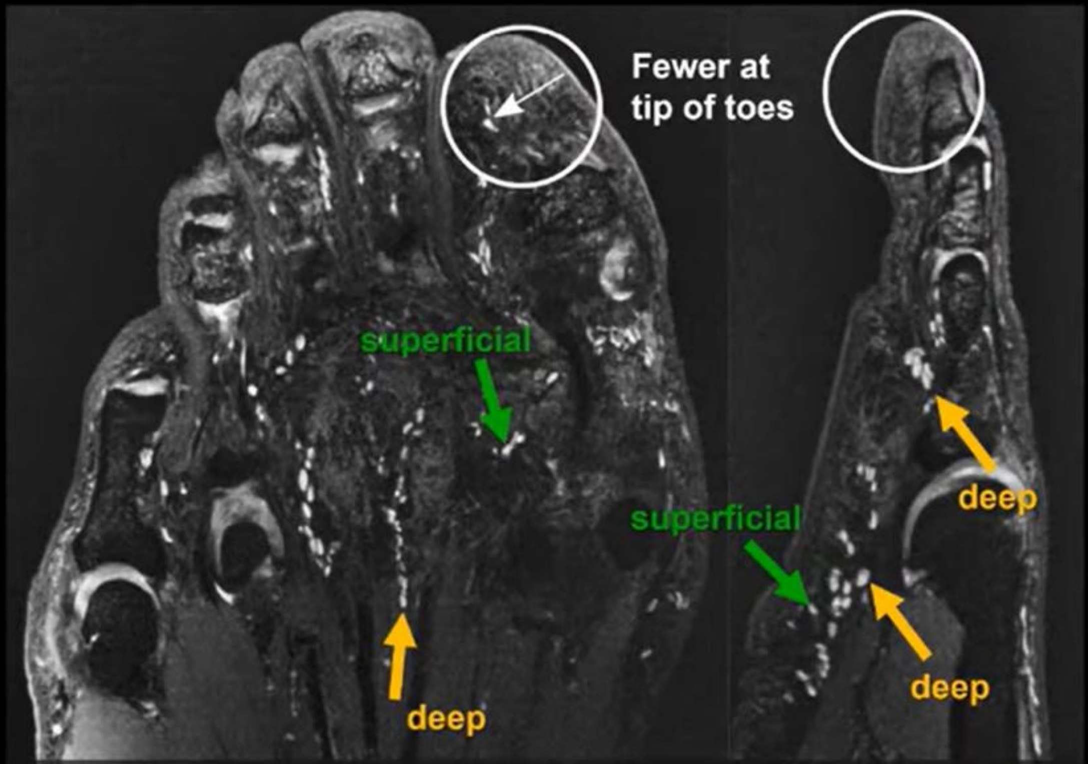
Balgrist

7T


New milestone for 7T MRI
Accelerated High-Resolution DL TSE of the Knee
PD fs TSE, 1.5 mm slice thickness,
0.31 mm pixel size, 4:05 min
SCAN ME!
#OpenAccess
University of Zurich
Marth AA, et al. Invest Radiol. 2024 Jul 4. doi: 10.1097/RLI.0000000000001095.
Balgrist

7T

Other 7T areas: Forefoot



3D DESS with partial maximum intensity projection (MIP)

Pacinian corpuscles

Mechanoreceptor: sudden disturbances, vibration

Mostly along plantar subcutaneous fat & along deep muscle fascia

SCAN ME!
#OpenAccess

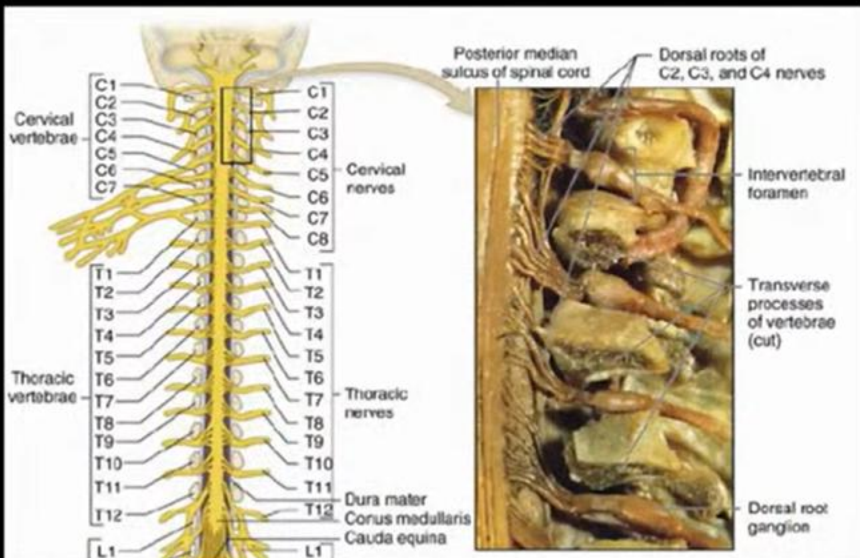
University of Zurich

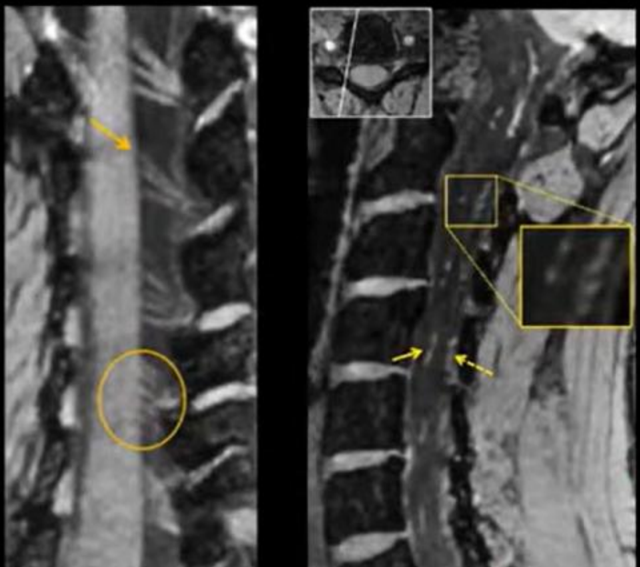
Germann, Sutter, Nanz. Skeletal Radiol. 2021; 50:1249-55.

Balgrist

Formazione per l'eccellenza

High-resolution 7T of the cervical spine





- **Cervical rootlets** visualized with positive contrast using 3D-DESS
- 7T superior for depiction of rootlets

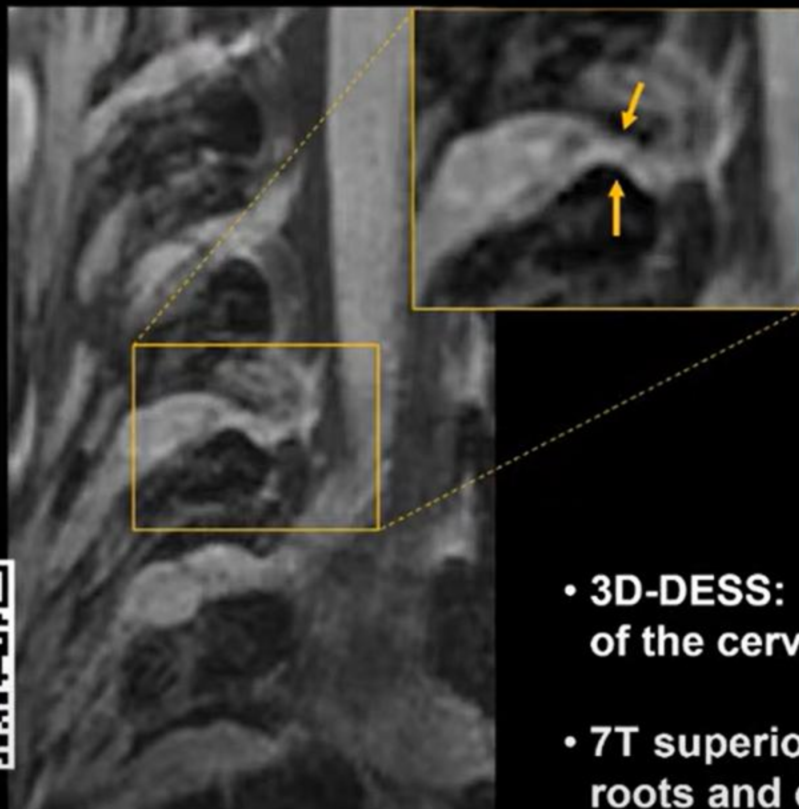
University of Zurich

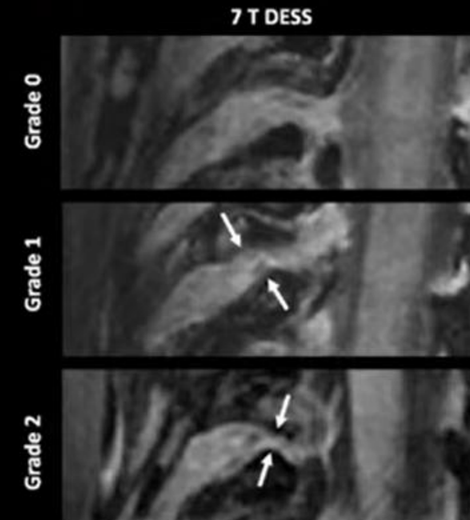
Galley J, et al. Eur Radiol. 2021;31(7):4625-4633.

Balgrist

Formazione per l'eccellenza

Cervical spine at 7T: Nerve root compression





- 3D-DESS: Direct assessment and grading of the cervical nerve root compression
- 7T superior for depiction of rootlets, nerve roots and dorsal root ganglia

SCAN ME!
#OpenAccess

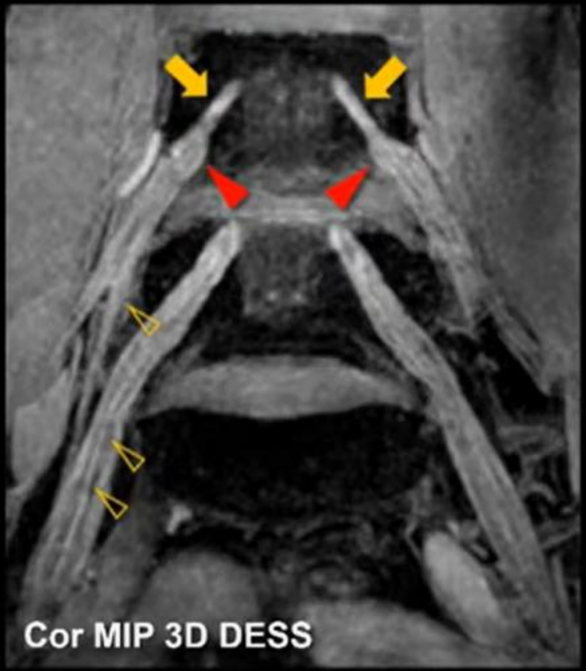
University of Zurich

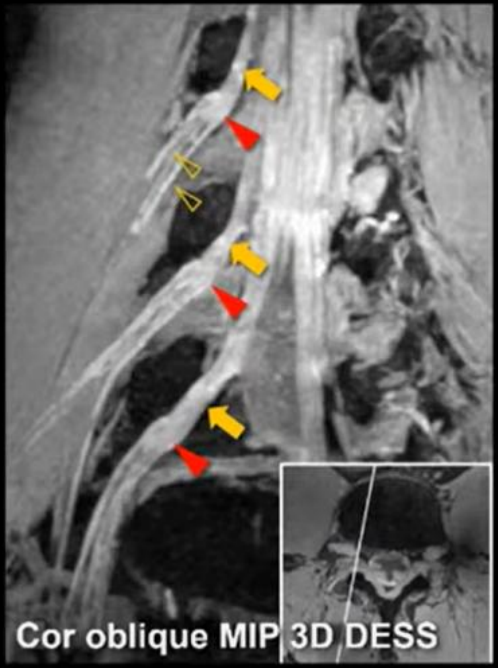
Feuerriegel GC, et al. Invest Radiol. 2024;59(6):450-457.

Balgrist

Formazione per l'eccellenza

7T MRI Neurography: Lumbosacral plexus





Visualization of single nerve fascicles

University of Zurich

Marth AA et al. Invest Radiol 2024, online before print.
doi:10.1097/RLI.0000000000001113

Balgrist

UNITED IMAGING

Shanghai United Imaging Healthcare Co., Ltd.

UNITED IMAGING

5.0T MRI

UNITED IMAGING 3.0T

uMR Omega

uMR 790

uMR 780

uMR 770

UNITED IMAGING

UNITED IMAGING 1.5T

uMR 680

uMR 670

uMR 588

uMR 580

uMR 570

UNITED IMAGING

UNITED IMAGING 1.5T

United Imaging To Introduce New Innovations at RSNA 2024

UNITED IMAGING

uMR®

The "Magnificent 5 cm Leap" from a 70 cm to 75 cm ultra-wide bore is complemented by unparalleled precision and world-class magnet homogeneity with the uMR OMEGA, the only ultra-wide 3T 75 cm bore. uAI DeepRecon is a deep learning-based reconstruction used to create higher resolution images and remove noise from the data, improving image quality for all body parts without extending scan times.

https://www.bruker.com/it/products-and-solutions/preclinical-imaging/mri/ultra-high-field-magnetic-resonance-imaging.html

BRUKER

Ultra High-Field Magnetic Resonance Imaging

Overview

Currently, most clinical MRI systems operate at moderate field strengths of 1.5 Tesla and 3 Tesla. For small animal imaging, resolutions need to be significantly increased in order to visualize similar structures as in humans. Since the sensitivity increases with the field strength, field strengths of 7 Tesla and 9.4 Tesla are therefore standard in the preclinical field. Beyond this, preclinical UHF systems ranging from 11.7 Tesla to 21 Tesla address specific applications, which demand the highest sensitivity. Even the most demanding applications become feasible when ultra high field strengths are combined with optimal coil setups, such as receive-only arrays, the sensitivity of which increases super-linearly with magnetic field strength, or MRI CryoProbes, which provide an even additional sensitivity boost.

Formazione per l'eccellenza

The advantages of UHF MRI go beyond the sensitivity gain itself. UHF MRI facilitates a range of imaging methods and applications. Increased chemical shift, increased Blood Oxygenation Level Dependent (BOLD) contrast, altered relaxation times, and increased susceptibility effects make it predestinated for several MRI methods such as MR Spectroscopy (MRS), BOLD Functional MRI (fMRI), Chemical Exchange Saturation Transfer (CEST), Susceptibility weighted Imaging (SWI), and Quantitative Susceptibility Mapping (QSM). Taken together UHF MRI can open up completely new avenues in the understanding of biological processes.

BioSpec 152/11

BioSpec 117/22

BioSpec 117/16

Bruker 9.4T MRI animal scanner

9.4T MRI technical specifications

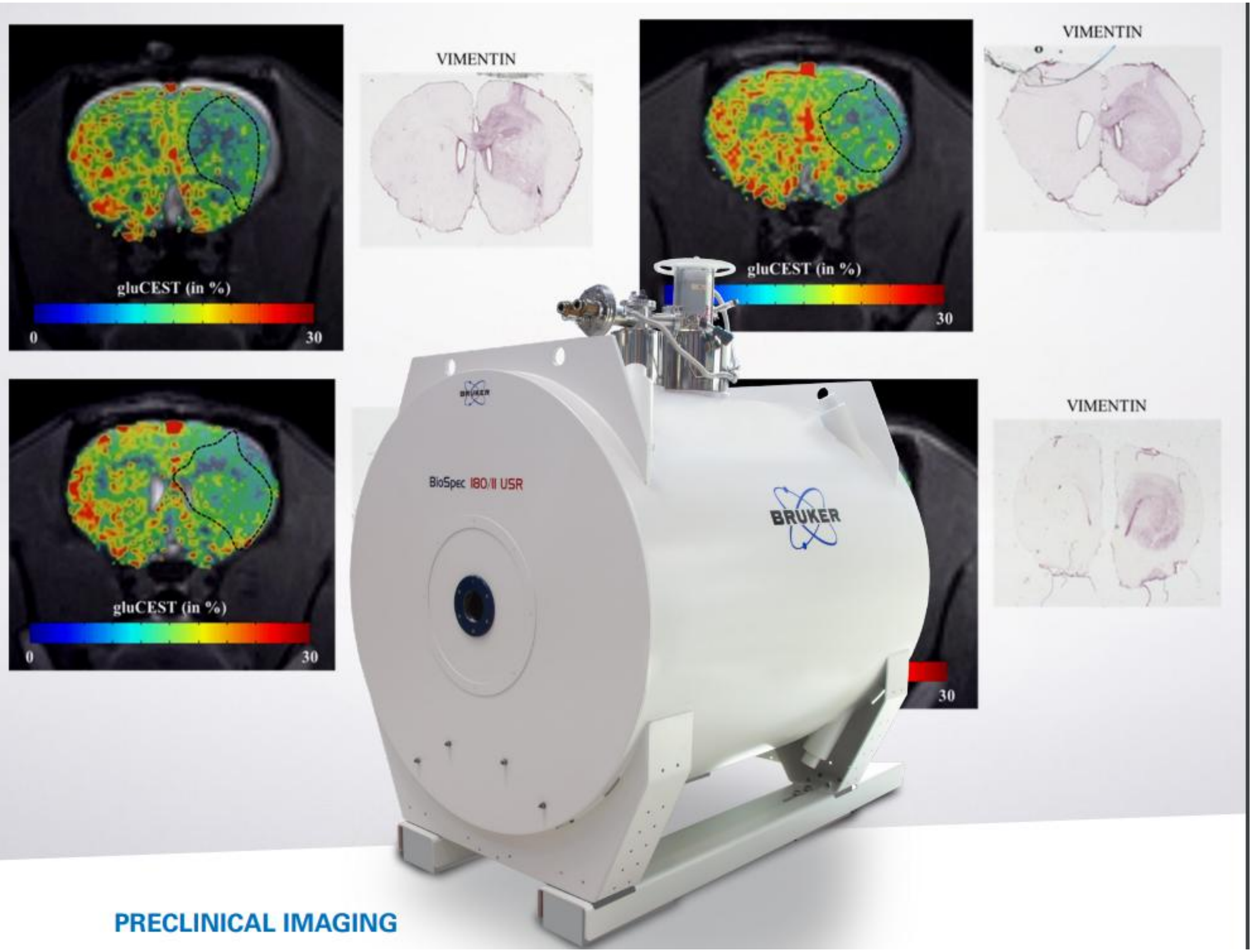
- Dual gradient coils
- Mouse and rat head array and surface coils for brain imaging
- Mouse and rat cardiac array coils for heart imaging
- Array coil for marmoset brain imaging
- 40mm 19F/1H dual channel fluorine imaging coil for mouse or samples
- 35mm volume coil for high-resolution mouse head/body or sample imaging
- 72mm volume coil for rat body or sample imaging
- 90mm and 86mm radio frequency transmit and receive coils
- Suitable isoflurane anaesthesia and animal monitoring system and heater to maintain animal temperature during the scan
- Full range of beds to cater for most species and samples

UHF MRI

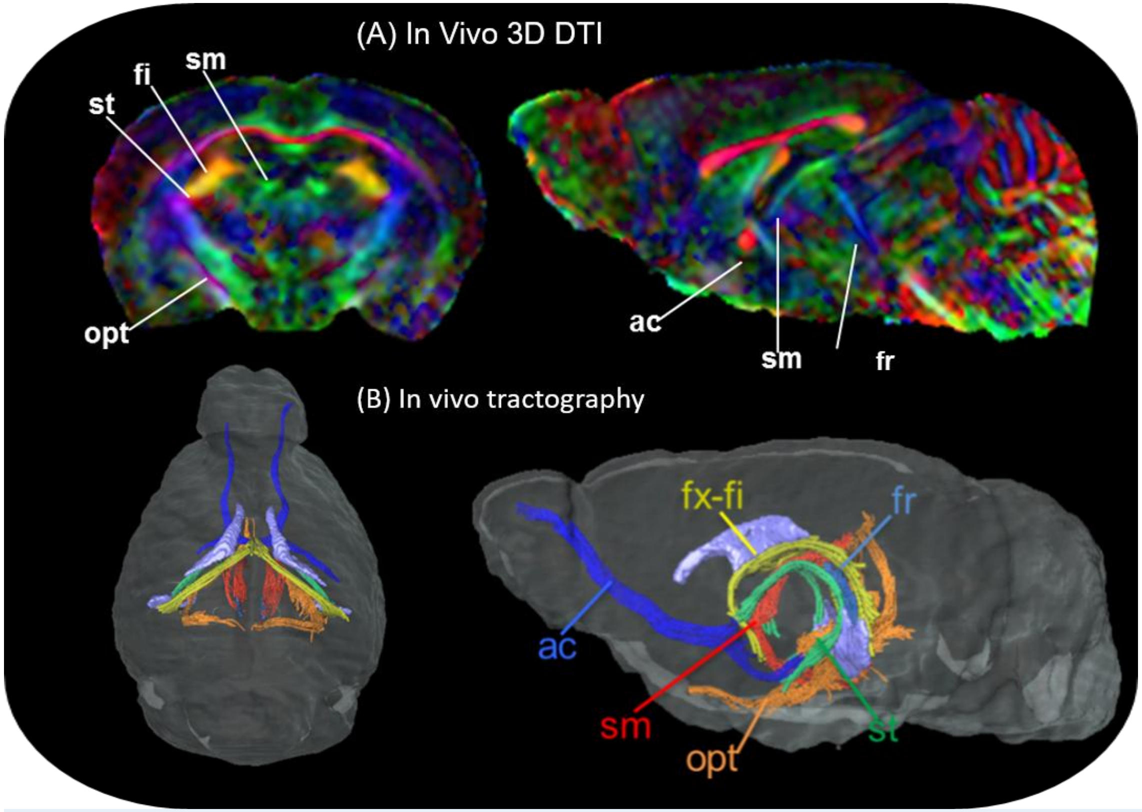
BioSpec Ultra-High Field

A Whole New World of MRI - 11.7 Tesla to 18 Tesla

Formazione per l'eccellenza



Cardiac FLASH MRI provides superior spatial and temporal resolution with visualization of all four heart chambers and aorta with 9 frames per heartbeat



The anterior commissure (ac), optical track (opt), fornix-fimbria (fx-fi), stria medullaris (sm), stria terminalis (st), and fasciculus retroflexus (fr) can be seen in DTI Courtesy: P. van Zijl, Kennedy Krieger Institute and Johns Hopkins University, Baltimore, USA

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Timeline of Remote Scanning Adoption

Remote MRI scanning is a relatively recent development, emerging gradually over the past 10–15 years, but accelerating rapidly since around 2018–2020.

Late 2000s – Early 2010s

- The earliest forms of remote MRI support appeared, mainly limited to:
  - Radiologists reviewing images off-site
    - *For urgent review of STAT exams.*
    - *If there were an off-campus location conducting radiology exams.*
    - *Allowed radiologists to view in real-time from another floor in a hospital.*
  - Engineers performing remote system diagnostics and software updates.
- Actual remote operation of scanning protocols by technologists was still rare and largely experimental.

Mid–2010s (~2013–2017)

- MRI manufacturers (e.g., GE, Siemens, Philips) introduced more advanced remote console access features primarily for service engineers.
- Some pioneering teleradiology companies and hospital networks began pilot programs allowing limited technologist remote control in research settings, but this was not widespread.

Timeline of Remote Scanning Adoption

◆ **2018**

- Early adopters in the U.S. and Europe began formalizing remote technologist workflow, especially in rural networks where staffing shortages drove demand.
- The idea of fully remote technologist-led scanning gained traction but was still in the early adoption phase.

◆ **2019–2021 (Pandemic Catalyst)**

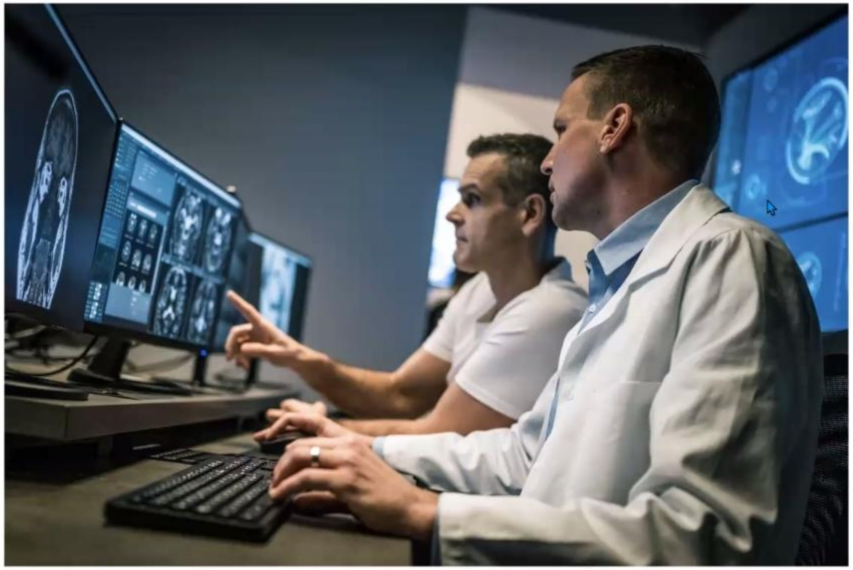
- COVID-19 drove a dramatic acceleration of remote scanning models while also driving an already depleted workforce deeper into a staffing crisis.
- Vendors upgraded platforms to allow secure remote access to consoles.
  - The onset of remote scanning pilots for clinical use.
  - Blueprinted the roadmap for what needs to happen to be successful. (i.e. onsite practitioner roles such as MRI Tech Aide)
- Accreditation bodies start to learn and recognize remote scanning into their standards and began approving protocols for remote scanning in earnest.

Formazione per l'eccellenza

Timeline of Remote Scanning Adoption

🔹 **2022–Present**

- Remote MRI technologist services have matured into commercial offerings, with dedicated providers contracting with imaging centers and hospitals.
- With the help of remote scanning companies, regulatory bodies and accrediting organizations clearer guidelines and recommendations have been created for MRI safety, credentialing, and compliance.
- Adoption has expanded significantly, especially in markets facing MRI technologist shortages.



While forms of remote MRI support date back over a decade, remote scanning as a structured service really began to emerge around 2018 and expanded substantially during and after the COVID-19 pandemic.

The overall goal and commitment is to ensure that patient care and MRI safety is in the drivers seat.

The Safe Push Forward

Formalize the MRI Tech Aide Role

The MRI Tech Aide program is a course focused on training allied health professionals to be confident MRI Safety trained, onsite practitioners. The sole responsibility for an MRTA are as follows:

- Retrieve patients from Zone I and conduct second MRI Safety Screening.
- Guide patients from Zone I to Zone II and have patients change into MR safe gown.
- Escort patients to Zone III and conduct final *virtual time out* with the remote technologist via face time tablet (third layer MRI Safety Screening, final check-off).
- Position and landmark patients in Zone IV.
- Observe, assist and communication with the patient during the MRI exam.

Part A: Curriculum

All MRI Tech Aides must complete an MRI Tech Aide Certificate Program which is currently offered by Alpha RT's learning platform. The program is as follows:

- **Syllabus Overview** - outlining responsibilities, expectations and MRI Safety Clearance.
- **Patient Care and Level II MRI Personnel Safety Training**
- **Medical Terminology** - including taking patient history.
- **MRI Systems** - magnetic strength, radio frequency systems and gradient systems (including hazards. i.e. MRI burns)
- **Anatomy, Positioning and Landmarking**
- **Emergency Intervention** - Hospital Codes, System Maintenance and Quality Assurance

Source: https://remotemriscanning.com/mri-tech-aide-mrta/

The Safe Push Forward

Part B: Clinical Requirements

The clinical requirements must be completed on patients in an MRI setting and must be verified by either a registered American Registry of Magnetic Resonance Imaging Technology (ARMRIT), registered American Registry of Radiologic Technologist (ARRT) technologist, or an individual from the administrative or managerial staff at an MRI imaging center.

Students are required to complete the following clinical requirements:
30 (observed) MRI Safety Screenings.
30 (observed) MRI Positioning activities for each body part.
30 (observed) MRI Landmarking activities for each body part.

Upon completion of Part A, students are required to participate and pass the MRI Tech Aide™ Certification Exam. Students are only eligible after completing Part A and Part B: Clinical Requirements.

As an MRI Tech Aide, to remain in compliance you must submit an annual Level II Personnel MRI Safety training CE on your certification date.

Approvals

RadSite recognizes the AlphaRT MRI Tech Aide™ Certificate Program meets RadSite's education requirements for on-site MRI health practitioners pursuant to RadSite's Remote Technology Policy [policy sec 1 (G)(ii)(b)(vi)].

RadSite™ Accreditation Reinvented

Source: https://remotemriscanning.com/mri-tech-aide-mrta/

The Safe Push Forward

Bifurcating the Traditional MRI Technologist Role

Remote MRI scanning is not only addressing workforce shortages—it is elevating patient safety by creating multiple layers of screening and verification. Unlike the traditional 1:1 model where a single technologist manages all steps, the 2:1 model pairs a remote MRI technologist with an on-site MRI tech aide, ensuring thorough safety checks at every stage.

Enhanced Safety Workflow:

✅ Pre-Appointment Screening
Patients complete a detailed safety questionnaire before arrival, flagging potential contraindications early.

✅ Zone 1 Screening (Waiting Room)
Upon check-in, patients are rescreened by front desk staff for implants, devices, or safety concerns.

✅ Zone III Screening (Control Area)
The MRI tech aide conducts in-person ferromagnetic screening, verifies patient identity, and confirms pre-screening results.

✅ Final Time-Out Procedure
Immediately before entering Zone IV, a "time-out" safety check is performed via secure video call (e.g., tablet FaceTime).

- The remote MRI technologist, MRI tech aide, and patient all participate.
- Final confirmation of safety screening, patient identifiers, and laterality is confirmed.
- Opportunity to ask questions or report last-minute concerns.

Impact:

- More Touchpoints: Multiple opportunities to catch errors before scanning.
- Improved Communication: Clear visual confirmation and collaborative decision-making.
- Greater Accountability: Each check point documented and verified by both on-site and remote staff.

Benefits and Concerns of Remote Scanning

Benefits

Empowering imaging centers with remote capabilities unlocks a range of valuable benefits, including:

Reduce scheduling delays
- Extension of hours of operations
- Increase days
- Opening earlier and closing later.

Increase patient care and MRI safety.
- Bifurcation of the traditional MRI Technologist role into:
  - ***Remote MRI Technologist***
    - focusing on overall MRI safety, patient care and diagnostic quality of the exam.
  - ***MRI Tech Aide***
    - first level of MRI screening - not the final.
    - preparing for the exam (i.e. changing coils, cleaning, organizing patient flow, positioning & landmarking, etc.)
    - additional eyes on the patient and receiving patient notes.

Increase financial performance
- Reduces MRI scanner downtime by having more reliable coverage.
- Decreases MRI personnel payroll - subcontractor vs employee.
- Reliable MRI staffing solution - no call outs, vacations or emergencies.
- Returns leverage back to employers vs high travel tech costs.
- Swifter patient turnover with additional support on site.
- Expert remote MRI technologist are able to scan anytime, anywhere.
- Ability to scan more diverse MRI exams globally and in rural areas.
- Potential use case for remote clinical MRI training - (80/20 rule)

Concerns

While Remote MRI Scanning offers clear advantages, it's important to address key considerations and potential challenges:

Financial Implications
- Purchase of remote scanning IT infrastructure.
- Vendor payment to third party remote scanning provider <u>or</u> cost of an internal remote scanning team.
- Remote scanning is a long term *reinvestment* rather than *assessment*.

Accreditation
- Not all accreditation agencies fully support remote scanning but some do with proper standards.
- Contact your accreditation agencies to learn about recommendations.

Effects on Patient Care and MRI Safety
- Some radiology leaders believe that there will be a change in patient experience and a reduction in MRI Safety.
  - Reminder that a thorough MRI Safety workflow could in fact increase MRI Safety.
  - Bifurcating the technologist role, from 1:1 supervision to 2:1 supervision (more eyes on the patient additional level of screening, communication and verification = increase MRI safety)

Conclusion

Conclusion: From Shortage to Solution

✅ **Remote MRI scanning is not just a response to a crisis—it's a scalable, sustainable model**

- Addresses the urgent MRI technologist shortage
- Enhances patient safety through a layered, collaborative workflow
- Offers operational flexibility and financial efficiency for imaging centers

✅ **The MRI Tech Aide model formalizes essential onsite support**

- Provides trained and certified onsite professionals to support remote technologists
- Adds additional layers to traditional MRI safety screenings and patient care touchpoints

✅ **The future is hybrid: remote + onsite = better outcomes**

- Allows expert technologists to scan anytime, anywhere
- Expands access to MRI services, especially in rural and underserved areas
- Opens the door for future training models and global collaboration

"Technology alone doesn't solve workforce shortages—people do. Remote scanning empowers both."